STUDIES ON THE EFFECT OF RATES AND METHODS OF FYM APPLICATION AND SEED RATES ON LATE SOWN RAINFED WHEAT (*Triticum aestivum* L.)

THESIS

By

GURDIT SINGH

Submitted

to

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CERTIFICATE I

This is to certify that the thesis entitled " Studies on the effect of rates and methods of FYM application and seed rates on late sown rainfed wheat (*Triticum aestivum* L.)" submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy (Agriculture) in the subject of Agronomy and Agrometeorology of the Himachal Pradesh Krishi Vishva Vidyalaya, Palampur, is a bonafide research work carried out by Mr.Gurdit Singh son of S.Bhagat Singh under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of this investigation have been duly acknowledged.

Palampur
November 10 ,1987

(R.C.Thakur)
Chairman
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C E R T I F I C A T E II

This is to certify that thesis entitled " Studies on the effect of rates and methods of FYM application and seed rates on late sown rainfed wheat (*Triticum aestivum* L.)" submitted by Shri Gurdit Singh, Admission No. P 81-A4-Ph.D in partial fulfilment of the requirements for the Degree of Doctor of Philosophy (Agriculture) in the subject of Agronomy and Agrometeorology has been approved by the Examining Committee after oral Examination of the same in collaboration with the External Examiner.

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Dedicated to

The respectful and everlasting memory of my
Beloved father
Late Sardar Bhagat Singh ji Datta
who left for heavenly abode during the
progress of this work.

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(Gurdit Singh)
Admn. No. P-81-A-4-Ph.D

Palampur
November 16, 1987

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1. INTRODUCTION

Wheat is the most important grain crop both in regards to its antiquity and its use as a source of human food. It serves as a staple food for about one billion people in as many as 43 countries of the world. It provides about 20 per cent of total food calories for human race.

In India out of the total cultivated area of 23.6 million hectares about 72 per cent is rainfed and it accounts for 45 per cent of total food grain production of the country. Out of the total precipitation about 80 per cent is received during Kharif season. Thus a very low percentage of precipitation is left for the winter crops. While on one hand sowing of the crop immediately after the harvest of the Kharif crops is not possible due to non-availability of suitable varieties for early sowing, on the other hand sowing at times is delayed as late as last week of December or even upto first fortnight of January due to the late winter rains. Though at national level comparatively less area under wheat is rainfed but in the state of Himachal Pradesh wheat is cultivated on 84 per cent of the cropped area as rainfed crop. From 376.3 thousand hectare of area under wheat, the total production is only 303.4 thousand tonnes including that from the irrigated area. The average yield of wheat in the state is only 810 kg/ha which is quite low as compared to the national average of 2217 kg/ha (Anonymous, 1985).

Increase in rainfed wheat yield through improved production technology is one of the possible ways of improving the total food grain production. So, there is urgent need to analyse the problem of rainfed wheat farming and to develop suitable techniques for increasing the productivity of wheat under these rainfed conditions.

Farmers in rainfed area face the problem of poor seed germination, late sowing resulting in delayed germination and poor tillering due to low winter temperatures. This results in low plant density.

Fortunately, farmers have wheat variety S-308 (Sonalika) which is quite suitable for delayed sowing. Inspite of its suitability for delayed sowing, the problem of low soil temperature during the months of December and January have to be tackled. At the same time the low temperature which causes poor tillering and plant growth has got to be neutralized by certain agronomic manipulations.

It has been noted that reduced plant growth and yield to some extent can be compensated by increasing seed rate. Bains (1969) recommended that the use of higher seed rate with closer row spacing with ridge planting can give good wheat yield under late sown conditions. Reducing soil albedo and increasing the roughness of soil may help in raising the soil temperature by absorbing more heat from the sun and minimising the range between maximum and minimum daily temperatures. Mulching may be of great significance in this aspect. Spreading of some external materials on the soil surface or their incorporation into the soil may raise the soil temperature and hence modify the vegetative growth of the photoinsensitive dwarf wheat cultivars enabling them to yield vigorously. Use of mulch has been found to arrest the incoming radiation and enhance the soil temperature during winters (Jack et al.,1955). The use of farm yard manure (FYM) which is black in colour may be quite useful. Waggoner (1960) reported that in late sown when plots were covered with FYM it hastened the germination by 2-3 days. This was the result of increased soil temperature (1 to 2°C) Reduction in the surface albedo, absorption of more solar heat resulting in a rise in soil temperature by the use of FYM has also been reported respond from IARI (Dayanand et al.,1972). The use of FYM, therefore, can help in solving some of the problems of late sown rainfed wheat.

The benefits of FYM as a mulch can however, be derived if it is spread on the soil surface. Such a practice, though quite common with the farmers in the State but may result in nitrogen losses due to denitrification. However, the low temperature that prevail during the wheat growth may reduce such losses. However, there are no precise information available on the possible soil moisture content and temperature moderating effects of FYM when used as a mulch.

In view of the above mentioned facts the present investigation entitled "Studies on the effect of rates and method of FYM application and seed rates in late sown rainfed wheat (*Triticum aestiv um* L.)" was carried out during three rabi seasons 1982-83, 1983-84 and 1984-85 with the following objectives:

1. To assess the optimum seed and FYM rates for late sown rainfed wheat under mid-hill conditions of Himachal Pradesh,
2. to find out the suitable method of FYM application for higher yields,
3. to study the effect of farm yard manure application on the physico-chemical properties of soil,
4. to assess the nutrient status in respect of N, P and K under different FYM treatments, and
5. to observe the interaction effect among seed rates, FYM levels and methods of FYM application if any.

2. REVIEW OF LITERATURE

Wheat (*Triticum aestivum* L. em. Thell) is the world's leading cereal crop cultivated over an area of 230 million hectares with a production of 510 million tonnes. Out of this, in India, the total area under wheat is 23.6 million hectares with a production of 44.2 million tonnes contributing about 9 per cent of the total wheat production of the world. India stands 6th among the major wheat growing countries of the world (Anonymous, 1986). About 40 per cent area of the country is rainfed. The huge development cost in further extending the area under irrigation deters its faster expansion. Agriculture, more so the wheat cultivation will, therefore, continue to be rain dependent for many more decades to come.

Wheat is also one of the most important crops of Himachal Pradesh, occupying the highest acreage of about 376.3 thousand hectares and production 303.4 thousand tonnes with an average yield of 8.1 q/ha in the Pradesh which is quite low against the All India average yield of 18.73 q/ha (Anonymous, 1985).

Besides other factors, lack of adequate irrigation facilities in the state is an important yield limiting factor. Only 16.5 per cent of the wheat area in the state is irrigated. Therefore, the sowing of wheat in majority of the rainfed area is governed by autumn rains. Many a times on account of delayed rains sowing is often delayed upto the 3rd week of December or first fortnight of January. Experience has shown that the delayed sowing results in reduction of yield. The scarce winter rains further contribute to reduced yields.

The success of stabilizing the yield will, therefore, lie in the adoption of suitable agronomic practices like water harvesting and making the best use of available rain water by altering seed rate and applying farm yard manure through proper method of application. The present study pertains to the effect of rates and methods of farm yard manure application and seed rates in late sown rainfed wheat. The literature pertaining to the present investigation has been reviewed as under:

2.1. Effect of seed rates

2.1.1. Growth and development

Short height has been found to be influenced by the competition experienced by the plant for light, nutrient etc., which in turn is governed by the seed rate. Although the plant height does not differ under various seed rates during the early stage of growth, the differences become pronounced with the advance in age (Singh and Alam, 1944). Contrary to this Kiesselbach and Lyness (1948), however, pointed out that differences in height at maturity of wheat plants were not significant even due to the big change in seed rate, which varied from 45 to 90 kg/ha. Mangukia (1953), Das and Verma (1957), Solomn and Patil (1958), Nelson (1960), Tandon and Mishra (1960), Stevens (1965), Gupta (1966), Mathur (1966), and Malik (1969) also made similar observations. It may therefore, be inferred that the influence of seed rate of wheat on plant height is not uniform.

Kiesselbach and Lyness (1948) found that the number of tillers per plant decreased progressively from 3.8 to 3.0 with increase in seed rate to double. This was corroborated by Argikar and Patil (1957), Nelson (1960), Chaudhry and Khalid (1961), Stevens (1965), Rai (1966), Malik (1969) and Dubey and Lal(1970). Tandon and Mishra (1960) obtained the maximum number of tillers (11.88) with the seed rate of 22.5 kg/ha. The mean tillers per plant were 5.75 and 2.83 at seed rate of 50 and 100 kg/ha, respectively. The number of grain bearing tillers was maximum (3.32) when the seed rate was 45 kg/ha. This number decreased progressively with an increase in seed rate (Pendelton and Dungan, 1960). Sumbali and Sharma (1973) reported that the number of tillers decreased with the increase in seed rate. Contrary to this Randhawa and Jolly (1974) demonstrated that the seed rate had a pronounced effect on number of tillers per metre row length. However, Borse and Mahajan (1980) reported that an increase in the seed rate from 50 and 100 to 150 kg/ha resulted in significant reduction in the number of productive tillers per plant.

Stickler (1962) observed that the 1000-grain weight had a tendency to fall with the increased seed rate. Mahendra and Sharma (1976) also reported that increasing seed rate from 75 to 125 kg/ha increased plant density but decreased 1000-grain weight and number of grains per ear.

Likewise Sandhu et al. (1975) also concluded that an increase in the seed rate from 50 to 100 or 150 kg/ha resulted in significant reduction in the ear length and grains per ear but the 1000-grain weight remained unaffected. However, reports contrary to this were also available which suggested that seed rate had no influence on growth characters. In a report of Department of Agriculture, Eire (1950) it had been indicated that seed rate of wheat (winter and spring type) and oats had no significant effect on growth characters. Low rate of seeding gave more vigorous plant which were better able to withstand adverse conditions and generally had a more luxurious foliage. However, the lower ear weight at higher rate of seeding was compensated by the higher plant population.

In a latter study, Kingra et al. (1963) reported that culms per square foot, height and vigour were much affected by seed rate while 1000-grain weight and yield were less affected.

From the foregoing discussion it can be concluded that there was an inverse relationship between the seed rate and growth characters. Increase in seed rate increased the plant density but resulted in a decrease in plant height, number of tillers, length of ear head, grain weight/ear and 1000-grain weight.

2.1.2. Yield

Seed rate is the major factor which has considerable influence on the yield of late sown wheat, Mitra (1949), Boyd (1952) and Woodward (1966) concluded from several experiments that a very high seed rate instead of pushing the yield, had resulted in lower grain yield because of production of weeker plants. But for late sowing, optimum seed rate was 150 kg/ha. Stickler (1962) received highest grain yield with the increased seed rate. However, Nelson (1960), Chaudhary and Khalid (1961), Rai (1966), Malik (1969) and Dubey and Lal (1970) were of the opinion that doubling the seed rate reduced the grain yield. From an earlier study Bhardwaj and Wright (1967), however, recommended that the seed rate of 150 kg/ha with 15 cm row spacing can be adopted as a normal practice for late sown wheat crop.

On the contrary, Dubey and Lal (1970) and Upadhya and Chaudhari (1971) reported that the higher seed rate reduced the grain yield. However, Singh et al. (1971) found that 100 to 125 kg seed rate/ha was optimum seed rate for timely sown wheat. But for late sowing, optimum seed rate was 150 kg/ha . Vez (1972) also reported that amongst 3 sowing rates (75, 150, or 250 kg seed/ha) in case of spring wheat grain yield was higher with 150 kg seed rate/ha than 75 kg but there was no further increase in yield by increasing the sowing rate to 250 kg/ha. Similar were the findings of Bishnoi and Gill (1972), Bains and Bhardwaj (1972), Borse and Mahajan,(1980), and Rana (1980).

Sharma (1967) demonstrated that 98.8 kg/ha seed rate gave the higher straw yield. Likewise Dubey and Lal (1970) reported that a seed rate of 90 kg/ha proved superior to 60 kg/ha. In conformity to this Sinha and Singh (1970) have reported higher yields with sowing of 100 kg/ha under Sabour (Bihar) conditions. In a later study at Hissar, Agarwal et al.(1972) also reported highest grain yield with 100 kg seed rate per hectare. Nadagoudar and Patil (1973) also reported highest net income at a sowing rate of 100 kg/ha. Likewise Dhiman and Kalra (1978) reported that in case of triticale also 100 and 125 kg/ha seed rates resulted in significantly better yield over a seed rate of 75 kg/ha under rainfed conditions.

Mahapatra and Leelavathi (1971), however, observed 3 seed rates 75, 100, and 125 kg/ha to be equally effective. Increase in seed rate did not bring any increase in yield. On the contrary, Agarwal et al.(1972) reported that under late sown condition 125 kg seed rate/ha was better. The mean effect of different seed rate was not significant though 100 kg seed/ha gave the maximum grain yield which is in agreement with the results obtained by Singh (1965), Bhardwaj (1966), Sharma (1967) and Gupta et al.(1968). However, the straw yield increased with every increase in seed rate. Bains and Bhardwaj (1972) obtained highest yield of Sonara-64 with seed rate of 125 kg/ha. However, the straw yield was significantly higher with a seed rate of 150 kg/ha over 100 kg/ha. Sumbali and Sharma (1973), Khurana and Guliani (1973) reported that the seed rate upto 125 kg/ha influenced the grain yield significantly. Also Mahendra and Sharma (1976) reported that increasing the seed rate from 75 to 125 kg/ha consequently increased the yield under Pantnagar conditions. Similar were the findings of Gupta et al.(1968), Dubey and Lal (1970), Upadhya and Chaudhari (1971), Kamla and Singh (1975), Dhiman and Kalra (1978) and Upadhya and Kuberber (1980).

On the contrary, Singh et al.(1975), Sandhu et al.(1975), Warsi and Singh (1975) also reported that the increase in seed rate from 75 to 125 kg/ha failed to raise the grain yield significantly.

From the foregoing review, the consensus generally goes in favour of medium seed rate of 125 kg/ha under late sown condition.

2.1.3. Nutrient concentration and uptake

There are no consistent reports available about the effect of different seed rates on the content of nutrient elements in the plants. Wheat plants have high nitrogen content in initial stages, which decreases subsequently with the advancement of crop age (Singh and Anderson, 1973). Concentration of nitrogen varies between plant parts which further changes at different stages of development. Young shoots contain 3.7 to 4.2 per cent of total nitrogen in stem and leaves but at maturity the content may fall to 1 per cent only (Terman,1979 and Waldran and Flowerday, 1979). Further, the increase in nitrogen content is faster in stem than in leaves (Halloran and Lee, 1979).

In respect of P content also Boatwright and Haas (1961) reported that concentration of P in the whole plant and in each of its component part was generally at a maximum at the earlier stage of growth. Singh and Gupta(1970) reported that the percentage of P in the plant was higher during early stages and decreased subsequently as the plant advanced towards maturity. According to Black (1970) the minimum plant P content needed for maximum dry matter at tillering and heading was 0.4 and 0.2 per cent, respectively.

Bolaria and Mann (1964) reported that the K content at the young stages 4, 8, 12 weeks and at boot stage was highest whereas phosphorus was lowest. The relationship was maintained at all the 4 stages of growth. But this relationship was different in the ear head. A higher percentage of N followed by K and P was found in the ear head.

Out of the total N absorbed by the wheat plant 41 per cent was absorbed by the wheat plant upto tillering, 18 per cent from tillering to heading and rest 41 per cent from heading to maturity (Anonymous, 1970). Mahapatra and Leelavathi (1971) studies the effect of different seed rates, 75, 100, 125 kg/ha and nitrogen levels, 60, 120, and 180 kg/ha and concluded that in general the plant population did not effect the response of nitrogen. However, during the year 1968-69 at Sumerpur the response of Kalyansona to nitrogen was affected due to varying seed rates of wheat. While the responses were of the same order to 120 kg N/ha (over 60 kg N/ha) for all the seed rates at 180 kg N/ha (over 60 kg N/ha) higher seed rates were conducive to higher nitrogen. The response of phosphate was not affected by the variation in seed rates at majority of centres. At Pusa farm, change in seed rate from 75 to 100 kg/ha at 30 kg P_2O_5 level and from 100 to 125 kg seed rate at 60 kg P_2O_5 level, increased the response of phosphate significantly. However, a reverse trend at some other centres was also observed.

Sharma (1986) reported on the basis of 3 years experimentation that a lower seed rate of 75 kg/ha recorded higher N content over other two seed rates at 90 days stage but at the latter stages of crop growth in general 100 or 125 kg seed rate/ha recorded higher N content. In general N uptake increased upto harvest stage. In the early stages, 100 kg seed rate recorded more N uptake, but at harvest it was more with 125 kg seed rate.

Like N content, P content was also more in the early stages of crop growth and declined at harvest. During first year and third year, the P content was maximum at early stages and increased upto 120 days stages in all the seed rates of 75, 100 and 125 kg/ha. But at latter stages the concentration was higher under 75 and 100 kg/ha. It was lowest at 125 kg/ha . P uptake increased with the age of the plant and it was maximum at harvest. In general 125 kg seed rate recorded more P uptake in comparison to other two seed rates.

Hundred kg seed rate recorded the highest K content at harvest and also the K uptake increased with the age of the plant.

2.2. Effect of Farm Yard Manure

2.2.1. Growth and development

Crop response to manuring depends on several factors related with soil, plant climate and organic matter itself. The magnitude of response, therefore, has been found to vary from place to place. Bains et al.(1968) suggested the application of farm yard manure (FYM) on the soil particularly to the late sown crop. The low soil temperature inhibits the germination of seed and causes delay in emergence and slows down the growth of the seeding. Spreading of FYM helps in increasing the soil temperature by increasing heat absorbance from the sun and thereby enhances germination and growth. Patil and Bhardwaj (1976) observed that the germination of late sown wheat was hastened by mulching with FYM @ 10 t/ha.

Sharma (1983) observed that FYM application to either wheat directly or to both rice and wheat crop in a sequence, resulted in improvement in all the growth parameters viz., plant height, number of shoots per unit area, dry matter accumulation and yield contributing characters. FYM application resulted in early ear emergence in wheat than control. In a study under Palampur conditions Ganai (1983) reported that FYM application in wheat resulted in significantly better growth of wheat, number of shoots m^{-2}, height of plant, dry matter accumulation at tillering, heading and harvest stage over control. Tomar et al. (1984) concluded that FYM application results in substantial and significant increase in dry matter yield of wheat. Gupta (1985) also observed that FYM application in late sown wheat caused a significant increase on the growth and development characters.

2.2.2. Yield

Wheat being a winter season crop is benefitted by the use of FYM in or on the soil through its beneficial effects in modifying the micro-environment around the wheat seed and plant resulting in better crop yield. In this part of review the findings of numerous scientists have been reported to show the effect of FYM rates as well as its methods of application on wheat yield.

Gaur et al. (1984) reported that application of 25 t/ha of FYM supplies 112 kg N, 56 kg P_2O_5 and 112 kg of K_2O. These quantities however, are not fully available to the crop in the year of application. Nitrogen is very slow acting and less than 30 per cent of it is generally available to the first crop. About 60 to 70 per cent phosphate and about 75 per cent potash becomes available to the immediate crop. Chandanani (1954) concluded that increase in yield of wheat could only be obtained with large quantities of FYM. He got 60 per cent increase with 25 t/ha of FYM and only 20 per cent increase with 10 t/ha. He therefore, recommended that 10-15 t FYM/ha (100 kg N/ha) should be applied 7 to 8 weeks before sowing of wheat to get good response. On the contrary, regular addition of FYM did not increase the wheat yield for all the times (Schnieder, 1980).

Singh and Sharma (1981) also reported that grain and straw yield, were significantly affected by the level of organic matter @ 20 t/ha resulting in maximum yield which was significantly superior to control. Similar were the findings of Zhezher and Surorov (1980), Lund and Das (1980) and Singh et al. (1980). Under Palampur conditions Ganai (1983) reported that application of 20 t/ha of FYM increased the yield about 37 per cent over control. Sharma (1983) however, reported that FYM @ 20 t/ha increased the wheat yield by 85 per cent over control.

Gupta (1985) while seeing the influence of P and FYM application on crop response in late sown wheat observed that the application of FYM @ 8 t/ha caused a significant increase in the yield of wheat over control (No FYM). The increase in yield over control was to the extent of 30 per cent and 40 per cent during 1982-83 and 1983-84, respectively.

Dhingra et al.(1972) however, did not obtain significant response of FYM application in case of late sown wheat. Regular addition of FYM have been found not to increase the wheat yield at all the time (Schnieder, 1980). Gaur et al.(1982) reported that response of wheat to FYM application at 12.6 t/ha ranged as low as 80 to 90 kg/ha in Gujrat and Delhi to over 250 kg/ha in Maharashtra, Madhya Pradesh and Bihar. Based on 210 experiments distributed over 31 research stations located in different states the response was a little over 200 kg/ha.

To obtain full advantage of FYM it need to be supplemented through chemical fertilizers.Singh et al.(1980) found significant increase in wheat yield by the application of 12 t/ha of FYM only when supplied with balanced N, P and K over NPK alone. Balyk (1981) reported that incorporation of FYM @ 5 and 10 t/ha resulted in a significant increase in grain production in the first year but during 3rd year the response was not significant. Jagtap and Shrigata (1982) obtained 3 q/ha additional grain yield by the application of 10 t/ha FYM over control.

2.2.3. Nutrient concentration and uptake

Balla (1981) observed 20.36 per cent increase in nitrogen concentration in maize stalks and wheat straw with FYM. The influence of organic matter in increasing the total N content of the soil had been observed in several field experiments (Kanwar and Parihar, 1962, Mandal and Jain, 1965; Prasad et al.1971; Sahu and Nayak, 1971;Mathan et al.,1978; Gill and Meelu, 1980 and Kapur et al. 1981).

Logunow and Kaszubiak (1964) also reported an increase in available phosphorus and potassium, with the application of 25 t/ha of FYM as compared to application of mineral nitrogen phosphorus and potassium alone. Kuzentsova (1965) reported a decrease with concentration of nitrogen, but an increase in the concentration of phosphorus and potassium in the grain and straw of winter wheat and barley by the application of dung. Haworth et al.(1966) observed that FYM @ 20 t/ha increased the yield of redbeet from 11.35 to 18.15 t/ha. The nitrogen content of leaves increased from 3.97 to 4.54 per cent. The phosphorus content increased slightly from 0.49 to 0.50 per cent and potassium content decreased from 6.04 to 4.43 per cent with the application of 20 t FYM/ha.

Olsen et al.(1970) observed the effect of manure application on soil and found an increase in content of organic N and available P particularly at higher rates of P application. Mann et al.(1973) found that increasing level of FYM application increased the N content in wheat grain. Besides N, Zn, Mn and B content in wheat also increased when the crop was fertilized with FYM. Boon and Venter (1976) reported the results of field trials, which showed significant increase in N content of leaves, ears and stem of wheat with the application of organic matter.

It can be concluded from the foregoing review that an increase in the levels of FYM results in an increase in N and P content and a decrease in K content in the wheat grain.

Sharma (1983) found that the uptake of N in grain and straw as well as total uptake by wheat was significantly influenced by FYM @ 20 t/ha. Jai Bhagwan (1985) reported that the application of FYM @ 10 t/ha increased the uptake of P which was maximum in grains and lowest in straw. Regarding the K uptake it was highest in straw and lowest in grain.

2.2.4. Effect of FYM on quality of wheat grain

As such FYM may not be instrumental in the synthesis of protein but may have its role because of nitrogen present in it. Higher the quantity of FYM more will be the amount of N supplied to the soil. At the sametime because of its slow reaction the nitrogen supplied through FYM may remain available to the plant for longer duration during the entire plant growth period. Bains (1953) reported that 60 kg N/ha produced wheat containing 10.5 per cent protein. Russell (1973) and Fernandez and Laird (1959) reported that N significantly increased the grain protein.

Coic and Alexinsky (1954) reported that late application of nitrogen increased the nitrogen content of grain and thus its gluten content and resulted in an improvement of milling and baking quality. Spillane (1962), however, reported a progressive increase in protein content by increased application of nitrogenous fertilizers, but this was not paralleled by the improvement in baking quality. Hojjati and Maleki (1972) observed that protein content of grain was constantly increased by each additional increment of N from 50-200 kg N/ha which was about 1 per cent for each addition of 50 kg N/ha. Austin and Ahuja (1974) observed an increase in protein content from 10.88 to 10.95 per cent in wheat cultivar Kalyansona and Hira with no N treatment to 12.54 and 13.36 per cent at 80 kg N/ha and 14.00 to 16.25 per cent at 160 kg N/ha. Antonyuk and Pogrebnyak (1976) also reported that application of 120 kg N/ha increased grain protein by 0.4 to 2.9 per cent.

2.2.5. Grain protein yield

In the foregoing review it has been shown convincingly that an increase in N levels whether through chemical fertilizers or through organic manures results in an increase in the N content of grains. This increase in N content of the grains will, therefore, result in an increase in the protein yield as well. Abdul Galil (1976) reported that grain N yield increased significantly from 49.52 to 74.28 kg/ha in 1972 and from 28.33 to 56.19 kg/ha in 1974.

2.2.6. <u>Effect of FYM on soil temperature and germination</u>

Organic mulches regulate soil temperature, control weeds and ameliorate the unfavourable physico-chemical properties of soil (Chaudhury and Chatterjee, 1967 and Black, 1973). Hanks et al.(1959) showed that the usual effect of mulch is to lower soil temperature during summer and increase during winter of its lower thermal conductivity as compared to that of bare soil. McCalla and Duley (1948) and Isenberg and Odland (1959) also made similar observations.

Wheat seeds sown in the plots covered with FYM as a mulch have been found to germinate 2-3 days earlier. This was the result of increased soil temperature. The soil temperature depends on the surface albedo and surface colour. FYM which is dull black in colour reduces the surface albedo, absorbs more solar heat and thus helps in raising soil temperature. Waggoner (1960). Collis-George <u>et al.</u> (1963) also noted that dark coloured mulches absorb the heat and raise the soil temperature. Rohmke and Verkhoven (1963) recorded the temperature of mulched and bare soil at 2.5, 10 and 12.5 cm depth. Average daily temperature of mulched and bare soil varied only slightly. In winter the mulched soil was warmer by 2°C than the bare soil. Raina <u>et al.</u>(1968) observed improvement in temperature by surface covering of FYM. This in turn hastened the germination of wheat. Boatright and Whitefield (1969) reported that ear formation in wheat was closely and positively related to the soil temperature in the initial growth stages. Moreover, microbial activities might have been increased under more favourable soil temperature occuring from mulch with FYM with a consequent increase in growth and yield of wheat.

In a later study Attia (1970) also reported that mulching treatments helped the wheat to perform better than 'no mulch' under late sown condition. FYM mulch was more effective than control. Dayanand (1971) observed that FYM cover acts as a black blanket over the soil and raises the soil temperature by 1.4°F to 3.4°F over no cover treatment and could enhance the grain production of late sown wheat by 15 to 23 per cent. Patil and Bhardwaj (1976) found that mulching with FYM @ 10 t/ha hastened the germination of late sown wheat. There was no difference in the effect of covered and uncovered plots in the morning but the soil temperature in FYM covered plots was higher by 1-2°C at noon and evening.

2.2.7. Effect of FYM/organic mulches on soil moisture conservation

Water is the most important single factor limiting crop production under rainfed conditions. The inadequacy and uncertainity of rainfall causes partial or complete failure of crops in these areas. Rainfall in these areas is insufficient and unevenly distributed. Therefore, successful cropping during Rabi season mainly depends on conservation of adequate moisture in soil profile. A large part of the stored soil moisture is lost through evaporation during crop growth period from the soil which could effectively be reduced by the use of mulches.

Any material used at the surface of the soil to reduce evaporation losses, keep down weeds and temperature fluctuations or to promote soil productivity may be defined as mulch (Jacks et al., 1955). Russel (1973) has defined mulches as application of layer of dead vegetable waste material such as straw, hay or old grasses, compost or FYM to the surface of the soil. Organic mulches also affect the physical and chemical properties of soil (Chaudhary and Chatterjee, 1967, and Black, 1973).

Attia (1970) reported that the mulching treatment helped the winter varieties to perform better than 'no mulch' under late sown conditions. FYM was more effective than charcoal mulch. Bansal et al.(1971) also suggested that when maintained at adequate levels, these materials have been found to result in increased water content in the soil through reduced evaporation. Similar were the findings of Adam (1966), Parihar et al.(1968) and Moody et al. (1963). Kanao et al.(1974) also obtained increased yield of wheat and barley due to the application of mulches but the increase was said to be the result of prevention of lodging due to mulching.

2.2.8. Effect of FYM on physico-chemical properties of soil and nutrient availability

Farm yard manure affects both physical and chemical properties of soil The organic matter content, an important factor in maintaining the fertility of soil and cation exchange capacity can be maintained at a higher level by the incorporation of FYM.

Srinivasan (1943) observed that plots treated with organic manures increased pore space, infiltration rate, organic matter and improved soil aggregation. Acharya (1949) feels strongly that injudicious use of fertilizers on lands without organic manures will lead to disastrous results by way of a rapid deterioration in the physical conditions and fertility level of soil. Russel (1950) reported that humic acid from organic matter helped to maintain iron and other trace elements in the available form in alkaline soils and phosphate in an available form in acid soils. Lyon and Buckman (1953) reported that FYM affects physical, chemical and biological properties of soil and has a lasting effect on fertility of soil. Bhowmick and Raychaudhuri (1953) reported that under Indian conditions the use of combination of organic manures and fertilizers would give the optimum results both in long and short term planning for improving soil productivity and maintaining the soil fertility.

With the incorporation of organic materials into the soil, these are acted upon by a variety of micro-organisms and there is a tremendous increase in their population (Ghildyal and Gupta, 1959; Gaur and Pareek (1974) and Balasubramanian et al.,1972). The products of organic matter decomposition of soil perform two distinct functions, one relates to its mere physical presence on the soil surface and the other to processes of biodegradation (Bhardwaj and Patil, 1982). Addition of organic matter into the soil influences the soil structure, bulk density and allied physical properties of the soil. During its biotransformation processes. The organic carbon is converted into CO_2 and the carbon bound plant nutrients becomes available to the growing plants. Addition of FYM also causes shifts in the microbial equilibria of the soil with subsequent rise or fall of certain group or sections of the microbial community. Therefore, organic manures play an important role in crop production.

Better structural conditions of the manured soil was associated with decrease in bulk density, increase in porosity and hydraulic conditivity of soil. Water retension characteristics and available water content of soils were also improved. Similar results have been reported by several other workers (Biswas et al.,1961; Prasad and Singh, 1980; Bhatia and Shukla,1982 and Gupta et al.,1983).

Havangi and Mann (1970) reported that application of 12.5 tonnes of FYM per hectare decreased the bulk density and increased the water stable aggregates, but there was no appreciable effect on water holding capacity of soil. However, application of FYM @ 10 t/ha did not show any influence on the physical properties of soil (Khanna *et al.*, 1975). Pharande and Biswas (1968) reported that the application of FYM in wheat crop increased the organic carbon and reduced the bulk density from 1.86 g/m^3 (control) to 1.71 (FYM treatment). The minimum bulk density is an index of soil structure. The structural index is significantly correlated with bulk density and available soil water. Raising the organic matter status of soil improved the physical property of soil and resulted in higher productivity and higher yield. Similar observations were recorded in some other studies also (Pal, 1969; Khanna *et al.*, 1975; Mudgal, 1979; Bhatia and Shukla, 1982 and Sharma, 1983).

In a study Sharma *et al.*(1979) recorded a significant reduction in plant height and tiller number, when bulk density of sub-surface layer (15-25 cm) was 1.42 g/m^3 or above. However, the total dry matter, grain yield and root growth of wheat were significantly reduced at still lower bulk density of 1.34 g/m^3. Similar results were also reported by Kar *et al.*(1976).

Decomposition of organic matter is generally accomplished by the release of plant nutrients. The influence of organic manures in increasing the total N content of the soil has been observed in several long term field experiments (Sen and Bando, 1962; Kanwar and Prihar, 1962; Choudhury and Vachhad 1965; Sahu and Nayak, 1971 and (Kapur et al., 1984). However, Shinde and Ghosh (1979) and Havangi and Mann (1970) observed no difference in total N due to continuous application of less than 10 t of FYM per hectare over the control. Mandal and Jain (1965), Gill and Meelu (1980) indicated that continuous use of organic manures increased the available N when compared with inorganic fertilizers Prasad *et al.* (1971).

Maurya and Ghosh (1972) showed that the long term application of manure improved the organic carbon content and which resulted in improved availability of available N and other available nutrients. Deb (1976) found that FYM increased the organic matter of the soil and improved the physical properties also. It is a good source of macro and micro-nutrients and provides food for micro-organisms.

Vyas and Motiramani (1971) observed that application of FYM @ 22.4 t/ha increased available P from native as well as added P.

Akin to these observations Shinde and Ghosh (1971) also indicated that both organic acids and humic fractions of decomposing organic matter were more efficient in releasing P from rock phosphate or tricalcium phosphate resulting in less P fixation in soil. Similar observations were also recorded by Datta and Srivastava (1963), Basu (1973) and Pareek and Gaur (1973).

The effect of FYM application had significantly increased the available K content of soil (Kanwar and Prihar, 1962a, Gill and Meelu, 1980 and Prasad et al 1982).

The effect of FYM application on cation exchange capacity has been reported in a few experiments and it was observed that this property of soil was favourably influenced by FYM application (Mandal and Pain, 1965 and Sahu and Nayak, 1971).

Biswas et al.(1971) reported on the basis of 15 years experiment from (1952-67) that the application of FYM (applied @ 17 t FYM + A/S/ha) decreases the soil pH to some extent. Debnath and Hajra (1972) observed that soil containing FYM and paddy straw maintained higher soil pH than control after 120 days of incubation. Similar were the findings of many other workers (Atkinson et al., 1958; Prasad et al.,1971 and Lund and Dass,1980). The reason responsible for increase in soil pH due to incorporation of organic materials may be due to quicker release of K from these materials. On the contrary, Singh et al.(1980) observed a decrease in pH of Siesozem soil of semi-arid region of Haryana. However, Kanwar and Prihar (1962b)reported a decrease in soil pH only at Hansi but at Ambala and Jallandar it remained unaffected due to the application of FYM. More or less similar observations were made by Gupta (1985) who reported that the application of FYM decreased the soil pH from 6.26 to 5.94 (5.4%) at first stage and from 6.32 to 5.88 (6.9%) at blossoming stage and from 6.45 to 6.05 (5.2%) at harvest stage in wheat variety (S-308). The results indicated that the application of FYM caused a decrease in soil pH at all the 3 stages of crop growth. This may be due to the production of organic acids after the decomposition of FYM.

3. MATERIALS AND METHODS

The present investigation entitled " Studies on the effect of rates and methods of farm yard manure application and seed rates on late sown rainfed wheat (*Triticum aestivum* L.)" was conducted for three consecutive years of *Rabi* 1982-83, 1983-84 and 1984-85.. The experiment was laid out at the Research Farm of H.P.Krishi Vishva Vidyalaya, Palampur (Kangra) on acidic soil of wet temperate zone of Himachal Pradesh. The details of materials used and the procedures employed for field operations and laboratory analyses to meet the objectives of the said investigation are described in this chapter.

3.1. Experimental site

3.1.1. Location

The experimental site is situated at 32°6' N latitude and 76°3' E longitude at an elevation of 1290 metres above mean sea level (m.s.l.) in the Palampur valley of Kangra district.

3.1.2. Climate

Agroclimatically the region is characterised as wet temperate humid zone (Verma, 1979) with severe winter and humid summers. The annual rainfall is more than 2500 mm out of which about 75 per cent is received during June to September, October to April are the months of least rainfall. May and June are the hottest months while December and January are the coldest ones.

Mean weekly meteorological data recorded at the departmental observatory have been depicted in Fig.1 and given in Appendix I.

The total rainfall received during the years of experimentation i.e. 1982-83, 1983-84 and 1984-85 was 2214.6, 1993.5 and 2248.3 mm, respectively. Out of this 739.0, 260.8 and 352.4 mm rainfall was received during the respective crop seasons. The temperature during the cropping seasons varied from 1.4°C to 28.1°C, 0.1°C to 35.0°C and 3.0°C to 31.8°C alongwith mean relative humidity from

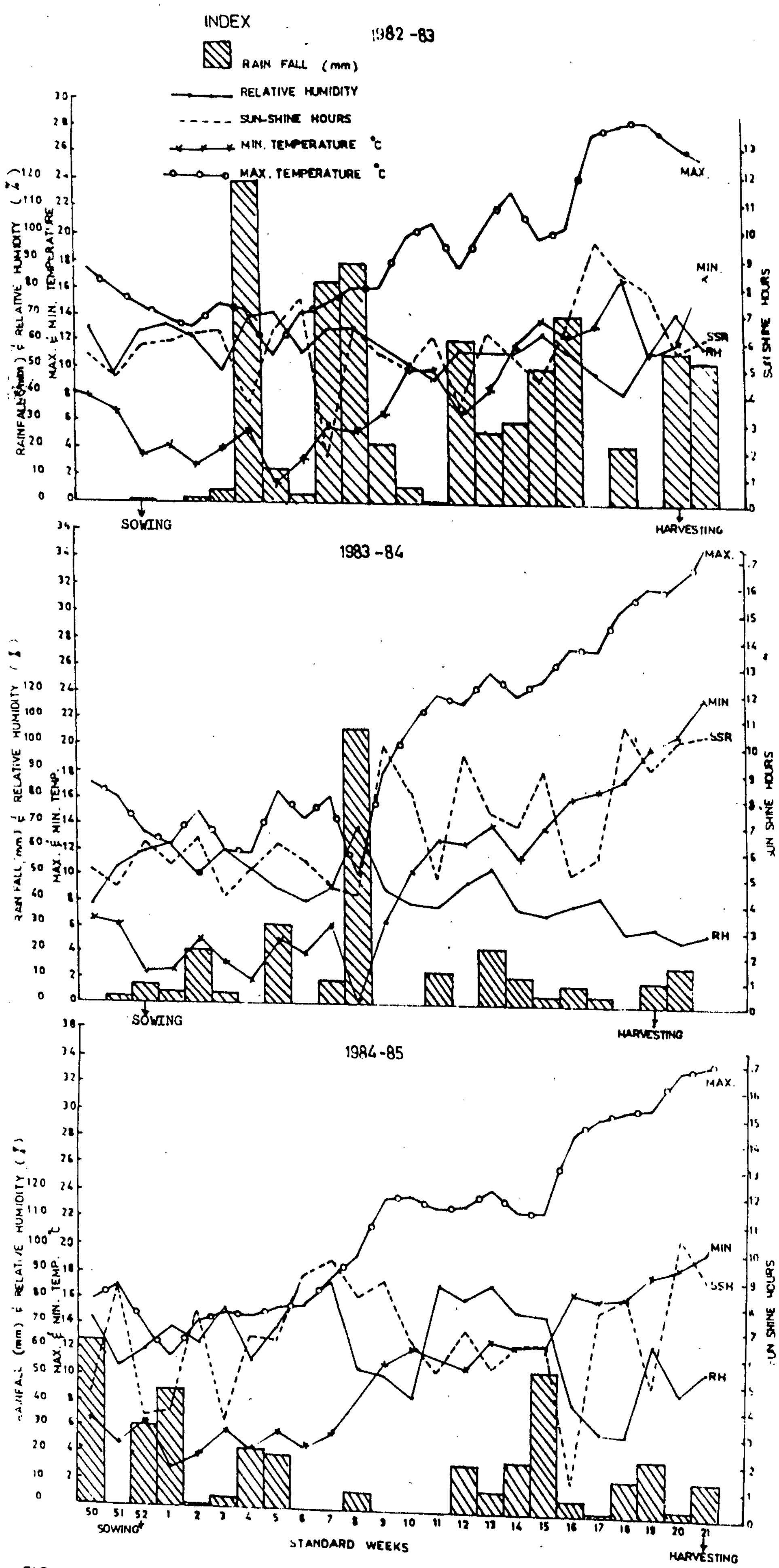

FIG. 1 WEATHER DATA DURING THREE CROP SEASONS

41 to 71, 31 to 70 and 30 to 87 per cent, respectively. As such, the experimental area therefore, represented sub-temperate humid climatic conditions.

3.1.3. Soils

The soils of the experimental plots which have been classified under Alfisol soil order and 'Typic Hapludalf' at the sub group level, while genetically are grey brown podzolic. These are basically of sedimentary and metamorphic origin, and the parent materials consist of granite, biotites, slates, schists, phyllites, quartzites, gneisses, sand stones etc. Development of these soils took place under high rainfall and mixed coniferous and deciduous vegetation and of grasses. The soil texture varied from sandy loam to silty clay loam. These soils are acidic in reaction ranging from pH 5.0 to 5.8, high in organic carbon, medium in available P with high P fixing capacity. The data pertaining to these physico-chemical properties of soil have been given in Table 1. The moisture content at field capacity and permanent wilting point was 26 and 12 per cent, respectively.

3.1.4. Cropping history

The experimental field was under rice-wheat cropping sequence for the two preceding years of the experimentation and prior to that the field was under rice-potato sequence. The complete cropping history starting from 1978-79 is given in Table 2.

Table 2. Cropping history of the experimental site

Year	Kharif	Rabi	Manuring kg/ha					
			Kharif			Rabi		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
1978-79	Rice	Potato	90	45	45	120	80	80
1979-80	Rice	Wheat	90	45	45	90	45	45
1980-81	Rice	Wheat	90	45	45	90	45	45
1981-82	Rice	Wheat	90	45	45	90	45	45
1982-83	Rice		90	40	40			
1983-84	Rice		90	40	40			
1984-85	Rice		90	40	40			

Table 1. Physico-chemical properties of experimental site

Analyses	Value 1982-83	1983-84	1984-85	Method and references
A. Mechanical analysis				
Sand (%)	30.4	30.4	33.1	International pipette method
Silt (%)	38.6	38.6	36.9	(Piper, 1966)
Clay (%)	29.8	29.8	24.2	
Texture	----Clay loam ------			
Moisture(%) Field capacity	26.8	26.5	25.2	Gravimetric method (Dastane, 1972).
Permanent wilting point	12.8	11.5	12.0	
Moisture(%) at sowing	18.8	20.0	22.5	
Bulk density	1.36	1.33	1.35	Core sampling techniques (Singh, 1980).
B. Chemical analysis				
pH	5.5	5.5	5.5	1:2.5 soil water suspension glass electrode pH meter method(Jackson, 1967).
Organic carbon (%)	0.5	0.5	0.5	Rapid titration method (Walkley and Black, 1934).
Cation exchange capacity (me/100g)	10.5	9.9	10.2	Extraction with 1N NH_4OAC pH 7.0 (Jackson, 1967).
Available nitrogen (kg N/ha)	418	378	371	Alkaline permanganate method (Subbiah and Asija, 1956).
Available phosphorus (kg P/ha)	15	12	11	Olsen's method (Olsen et al., 1954).
Available potassium (kg K/ha)	201	190	203	Neutral 1N NH_4OAC pH 7.0 extraction using flame photometer (Merwin and Peech, 1951).
Total nitrogen (kg N/ha)	850	864	915	Semi-microkjeldahl method (Bremner, 1960).
C. Composition of FYM (% oven dry basis used for experimentation)				
Dry matter (%)	70	74	69	Total NPK content of FYM was
N (%)	0.59	0.50	0.53	determined by the standard
P (%)	0.18	0.16	0.19	methods as described by
K (%)	0.60	0.47	0.56	Jackson, 1967.

3.1.5. Description of the field experiments

This field experiment was carried out for two consecutive years in Block B during 1982-83 and 1983-84 and Block C during 1984-85. Since the two blocks were adjoining to each other, therefore, they did not vary much in their initial physico-chemical properties. The details are presented below pointwise.

3.2. Experimental details

Treatments: All possible combinations of the following.

A. Seed rate : S_1 - 100 kg/ha
S_2 - 125 kg/ha
S_3 - 150 kg/ha

B. FYM rates: F_1 - 5 t/ha
F_2 - 10 t/ha
F_3 - 15 t/ha

C. Application method (FYM)
M_1 - Incorporation into the soil
M_2 - Surface application

D. Experimental design: $3^2 \times 2$ **factorial partially confounded design**

E. Number of replications: 4

Total No. of treatments : $3^2 \times 2 = 18$

Total No. of plots : 72

F. Treatment combinations

1. $S_1F_1M_1$	7. $S_2F_1M_1$	13. $S_3F_1M_1$
2. $S_1F_1M_2$	8. $S_2F_1M_2$	14. $S_3F_1M_2$
3. $S_1F_2M_1$	9. $S_2F_2M_1$	15. $S_3F_2M_1$
4. $S_1F_2M_2$	10. $S_2F_2M_2$	16. $S_3F_2M_2$
5. $S_1F_3M_1$	11. $S_2F_3M_1$	17. $S_3F_3M_1$
6. $S_1F_2M_2$	12. $S_2F_3M_2$	18. $S_3F_3M_2$

G. Plot size : Gross : 4.25m x 3.60m = 15.30m^2
Net : 3.50m x 2.70m = 9.45 m^2

Each replication of the experiment consisted of 3 blocks of 6 plots each. The treatments were allocated as per the procedure reported by Merrill, Kilby and Greer (1942). Plan of layout has been given in Fig.2. The field arrangement of replicates, blocks and plots has been shown in Fig.2.

3.3. Field operations

The schedule of various field operations performed during the crop seasons is given in Table 3.

Table 3. Schedule of field operations

S.No. Operation	Dates			Particulars of operation
	1982-83	1983-84	1984-85	
1. Seed bed preparation	15.12.82	15.12.83	15.12.84	One ploughing with tractor drawn plough followed by two harrowings and planking.
2. Layout	20.12.82	20.12.83	20.12.84	The layout was done as per plan given in Fig.2.
3. Sowing	24.12.82	24.12.83	24.12.84	FYM mixed with soil under M_1 treatments. Fertilizers were thoroughly mixed and applied in bands and seed put in furrows by Kera method
4. FYM surface application	24.12.82	24.12.83	24.12.84	Under M_2 treatment well rotton FYM was top dressed i.e. surface applied just after sowing.
5. Harvesting	20.5.83	12.5.84	27.5.85	The crop was harvested as described in Section 3.3.4.
6. Threshing	25.5.83	18.5.84	2.6.85	Done by plot thresher.

3.3.1. Seed and sowing

The seed of variety S-308 was sown in rows by Kera method with row spacing of 22.5 cm. Each plot had 16 rows.

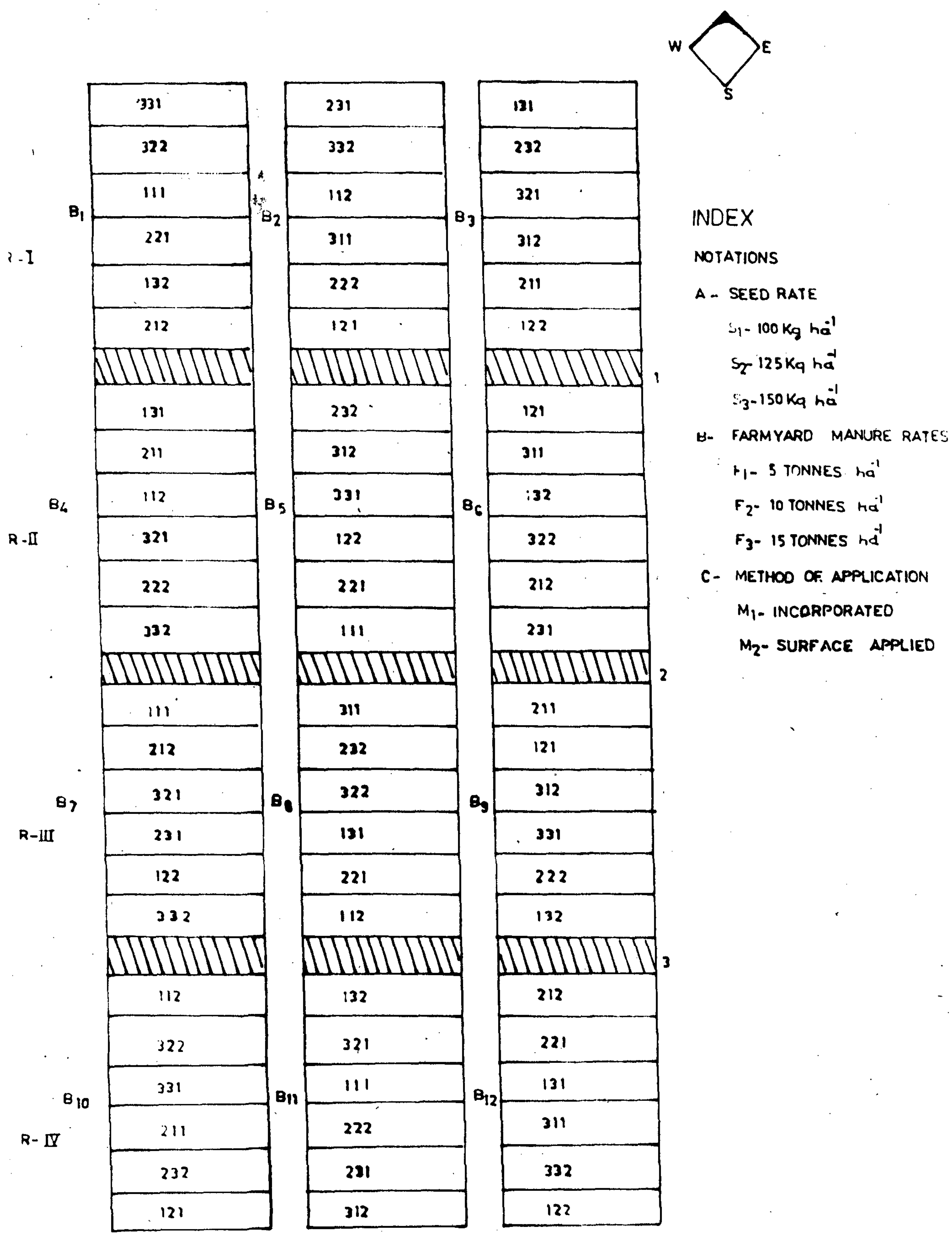

FIG. 2 LAY-OUT PLAN OF EXPERIMENT

3.3.2. Fertilization

All the plots received a uniform dose of 100 kg N and 30 kg each of P_2O_5 and K_2O/ha. The sources of fertilizers were Urea (46% N), Single superphosphate (16% P_2O_5) and Muriate of potash (60% K_2O). Entire dose of P and K and 60 kg of N was applied before sowing as a basal dressing by placement method after mixing all the three fertilizers thoroulghly. The remaining 40 kg N was applied after two months with the first shower of winter rains.

3.3.3. Application of FYM

In M_1 method of application, well decomposed FYM was mixed in soil before the application of chemical fertilizers at the rate of 5, 10, and 15 tonnes/ha, respectively as per treatment. In M_2 method, it was top dressed immediately after sowing @ 5, 10, and 15 tonnes/ha as per treatment.

3.3.4. Harvesting and threshing

Leaving two rows on each side and 37.5 cm length on each corner as the border area the crop in the net plots (3.50m x 2.70m) was harvested, bundled and weighed after field drying. The threshing of the individual plot was done with the help of plot thresher. The final produce of grain of each plot was weighed, recorded and converted into kg/ha.

3.4. Observations recorded

3.4.1. Emergence and growth studies

For recording observations 6 central rows leaving 5 rows on each side excluding one metre length on extreme ends of each plot were selected.

1. Days taken for germination: In each plot, two spots, each of 50 cm length were marked in the 6th and the 11th row of each plot at random and the seedlings emerged were counted from 14 days after sowing of crop. The observations were taken on every day. Days for complete germination were recorded by counting the shoots from the day germination started to the day when shoot number became constant.

Total days taken for complete germination from the date of sowing were calculated.

2. Initial plant population: Total number of shoots after complete emergence from 2 observational units of 50 cm row length were counted and the mean number of shoots were expressed as initial plant population per metre row length.

3. Shoot height: The mean height (cm) of 5 shoots selected randomly in net plots (3.50 x 2.70m) and tagged were recorded at 6, 9, 12, 15 and 18 weeks after sowing. The plant height was measured from the ground level to the tip of the fully opened young leaf and last observation was taken just before harvesting.

4. Number of shoots: The number of shoots per metre row length was counted from the 2 randomly selected plots in each plot at 6, 8, 10, and 12 weeks after sowing (WAS) and the final count was recorded at harvest. The number was expressed as per metre running row length.

5. Fresh and dry matter accumulation: The second row in each plot on both the sides was ear marked as sampling row from 2 spots each of 25 cm row length. The plant samples were cut at soil surface, weighed for fresh weight and then dried at 70°C for 24 hours to a constant weight and dry weight was recorded. Sampling was done at 6, 10, 14 and 18 weeks after sowing and at harvest. Fresh and dry weights thus obtained were expressed in ($g\ m^{-2}$) by multiplying the corresponding value of 50 cm row length with a factor 4.44 for each treatment separately.

6. Per cent dry matter: This was computed by using the following relationship:

$$\text{Per cent dry matter} = \frac{\text{Dry weight of sample } (g\ m^{-2})}{\text{Fresh weight of sample} (g\ m^{-2})} \times 100$$

3.5. Development studies

3.5.1. Days taken to 50 per cent heading

Days taken to 50 per cent ear emergence were recorded from half metre row length ear marked at 2 spots in the net plot for shoot number from the day head emergence started. The number of plants bearing spike were recorded on every alternate day till complete heading. The dates on which 50 per cent plant bore ears were recorded and number of days from sowing to 50 per cent heading were worked out.

3.5.2. 100 per cent heading

Number of days from sowing to 100 per cent heading were worked out as explained in case of 50 per cent heading.

3.5.3. Days to maturity

The date on which the maximum of the plants of individual plot had turned golden yellow was taken as the stage of maturity. This date was taken as maturity date and days taken to attain this stage are calculated plotwise from the date of sowing.

3.6. Studies at harvest

3.6.1. Number of spikes

From the 2 observational units of 50 cm length mean number of spikes per metre row length was recorded.

3.6.2. Spike length

Five spikes were taken randomly from 5 shoots and their length was measured from the base of the spike to the terminal end of the spike. Mean spike length was thus worked out and expressed in cm.

3.6.3. Number of spikelets per spike

From spikes which were used for spike length, the number of spikelets were counted and mean number of spikelets per spike was calculated.

3.6.4. Number of grains per spike

After recording the number of spikelets, 5 spikes were threshed and cleaned. The grains thus obtained were counted and mean number of grains per spike was recorded.

3.6.5. 1000-grain weight

Composite random samples from the produce of net plots were drawn and the 1000-grains were counted. These grains then were dried at 60°C in the oven for two days and weighed to record the 1000-grain weight.

3.7. Yield and harvest index

3.7.1. **Grain yield**

The produce from the individual net plot was harvested, threshed and cleaned. The weight of grain per plot was recorded in kilograms. The grain yield per plot so obtained was expressed as kilograms ha^{-1} which was obtained by multiplying the yield per plot with a factor 1058.20.

3.7.2. Straw yield

Total biological yield (grain + straw) from the net plot was recorded after sun drying of harvested produce. The straw yield was worked out by subtracting the grain yield from the biological yield and expressed in kilograms per hectare.

3.7.3. Harvest index

Harvest Index was worked out using the following relationship:

$$\text{Harvest index} = \frac{\text{Grain yield (kg/ha)}}{\text{Biological yield (kg/ha)}}$$

3.8. Plant chemical studies

The plant samples collected for recording the dry matter accumulation at different stages of growth were ground and analysed for total N, P and K contents. The uptake values for total N, P and K at different stages were calculated by multiplying per cent concentration with dry weight and dividing by 100. At harvest the grains and straw were analysed separately for N,P and K content.

The uptake at harvest was calculated on the basis of relative percentage of the nutrient elements in grain and straw. In the experimental results particularly at harvest stage the aggregate value of the concentration and uptake of grain and straw have been described. Both the values of grain and straw have separately been given in Appendices X ,XIV and XVI.

The methods employed for these chemical analyses are detailed in Table 4.

Table 4. Methods followed for plant analysis

Sr. No.	Particulars	Methods employed
1.	Nitrogen	The digestion was done with Conc.sulphuric acid and nitrogen content was estimated by modified Kjeldahl's method (Jackson, 1967).
2.	Phosphorus	Digestion with triacid mixture (HNO_3, H_2SO_4 and $HClO_4$ as 10:1:4) and phosphorus estimated by developing Vanadomolybdo phosphoric acid of yellow colour (Jackson, 1967).
3.	Potassium	Estimated by using flame emission spectrophotometry method for the extract obtained by digestion with triacid mixture for phosphorus above (Jackson,1967).

3.8.1. Protein content

The nitrogen percentage in grain was multiplied by 6.25 to determine their crude protein content.

3.8.2. Total crude protein production

The total crude protein production/ha in grain was calculated by using the following relationship:

$$\text{Crude protein(kg/ha) in grain} = \frac{\text{Per cent protein x grain yield/ha}}{100}$$

3.9 Soil Studies

3.9.1. Soil temperature

For recording soil temperature digital thermometer was placed at 5 cm depth in each plot randomly at 3 places. The soil temperature was recorded daily between 12 noon to 2 P.M. for two months w.e.f. 13.1.83 from the start of seed emergence. The temperature could not be recorded during 1983-84 season but this observation was again taken during 1984-85 crop season. The observations were recorded from one replication only and means have been reported.

3.9.2. Soil moisture studies

In order to know the soil moisture status during the crop growth period composite surface soil samples from each plot (0-15cm) were collected at 7 days after every rainfall from sowing to harvest. After recording the fresh weight, the samples were dried in oven at 105°C and the moisture per cent was worked out by using the relationship:

$$\text{Per cent moisture} = \frac{\text{Fresh weight - Dry weight}}{\text{Dry weight}} \times 100$$

3.9.3. Soil fertility studies

Soil samples from individual plots were taken after harvest and analysed for available nitrogen, phosphorus and potash, total nitrogen, pH, cation exchange capacity(CEC), bulk density and organic carbon(O.C%) as per methods described in the Table 1.

3.10. Statistical analysis

The data collected and recorded for various growth, yield and yield contributing characters and other parameters observed during the course of investigation were subjected to the statistical analyses by the method of analysis of variance as advocated by Cochran and Cox (1970). The data expressed in percentage were transformed, using square root or arc sine transformation as per the procedure suggested by Gomez and Gomez (1976) and then subjected to analyses. The critical differences in treatments were tested at 5 per cent level of significance (C.D. 5%). Only those interactions which were significant either for two years or more or were significant in the pooled analysis have been described in the experimental results. The interactions which were significantly only for one year have been given in the Appendix section.

4. EXPERIMENTAL RESULTS

The results of the current investigation entitled "Studies on the effect of rates and methods of farm yard manure application and seed rates on the late sown rainfed wheat (Triticum aestivum L.)" conducted during Rabi 1982-83, 1983-84 and 1984-85 have been described in this chapter. The data for the individual years have been presented through data tables and wherever necessary, the average values have been illustrated graphically also. The analyses of variance have been given in Appendix section.

4.1. Emergence and Growth studies

Observations on germination count and the characters like number of shoots per metre row length at 6, 8, 10, and 12 weeks after sowing (WAS), shoot height at 6, 9, 12, 15 and 18 WAS, green and dry matter and per cent dry matter accumulation at 6, 10, 14 and 18 WAS and at harvest have been recorded and explained in this section under the following sub-heads.

4.1.1. Germination count and number of shoots

The data pertaining to the effect of different treatments on germination count and number of shoots at different stages have been presented in Table 5. The corresponding analyses of variance have been given in Appendix II. The main effects have also been presented graphically in Fig.3.

A perusal of data presented in Table 5 indicates that out of the three years of experimentation, the seed rates influenced the germination count significantly only during first two years. During both the years it was observed that a high seed rate of 150 kg/ha (S_3) took comparatively lesser number of days for complete germination. In 1983-84 it differed significantly from 100 and 125kg seed rate/ha but in 1982-83 it differed significantly only from 100 kg/ha. The lower two seed rates remained at par with each other during these years also.

Table 5. Treatment effect on germination and number of shoots m^{-1} row length at various stages of crop growth

Treatment	Germination count: Days for germination from sowing till constant shoots 1982-83	1983-84	1984-85	No. of Shoots m^{-1} row length (Weeks after sowing (WAS)) 6: 1982-83	6: 1983-84	6: 1984-85	8: 1982-83	8: 1983-84	8: 1984-85	10: 1982-83	10: 1983-84	10: 1984-85	12: 1982-83	12: 1983-84	12: 1984-85	At harvest: 1982-83	At harvest: 1983-84	At harvest: 1984-85
A. Seed rate (kg/ha)																		
100	21.7	25.7	27.5	65.0	56.5	59.5	86.5	64.8	77.2	107.3	81.0	91.6	90.1	62.9	83.4	84.3	55.5	65.5
125	21.3	25.4	27.4	73.2	60.4	61.6	93.8	67.5	79.2	118.5	86.6	95.0	96.7	67.4	85.5	89.6	58.1	68.4
150	20.7	24.5	27.2	89.5	62.8	73.7	101.7	71.0	84.6	130.4	88.3	97.1	109.0	79.1	89.2	108.5	63.3	69.7
SEm±	0.2	0.1	0.1	1.1	0.9	0.7	1.1	0.9	1.0	1.2	1.3	0.9	1.0	0.8	1.7	1.3	0.7	1.0
C.D.5%	0.7	0.5	NS	3.3	2.6	2.1	3.3	2.7	3.0	3.5	3.8	2.6	2.5	2.5	3.6	3.6	2.1	2.7
B. FYM rates (t/ha)																		
5	21.6	27.7	27.8	74.5	57.2	59.5	89.8	61.8	76.2	108.5	78.9	90.5	93.1	69.4	80.9	90.7	56.0	65.3
10	21.3	25.1	27.3	76.0	60.2	64.0	95.1	68.6	77.5	121.2	86.3	94.2	99.6	68.2	85.5	94.9	58.9	68.7
15	20.9	24.8	27.0	77.3	62.2	71.2	97.1	79.9	87.3	126.4	90.7	99.1	103.1	71.9	91.8	96.8	62.1	69.7
SEm±	0.2	0.1	0.1	1.1	0.9	0.7	1.1	0.9	1.0	1.2	1.3	0.9	1.0	0.8	1.7	1.3	0.7	1.0
C.D.5%	NS	0.5	0.5	NS	2.6	2.1	3.3	2.7	3.0	3.5	3.8	2.6	2.9	2.5	4.9	3.6	2.1	2.9
C. Application methods																		
Incorporation	22.4	26.2	28.4	72.8	57.2	61.6	92.3	65.4	78.5	104.3	82.8	93.6	94.9	67.4	84.5	92.7	56.3	65.2
Surface applied	20.2	24.2	26.3	79.0	62.6	68.2	95.7	70.1	82.1	123.1	87.8	95.6	102.3	72.2	87.6	95.5	61.6	70.5
SEm±	0.2	0.1	0.1	0.9	0.7	0.6	0.9	0.7	0.8	1.0	1.1	0.7	0.8	0.7	1.4	1.0	0.6	0.8
C.D.5%	0.5	0.4	0.4	2.7	2.2	1.7	2.7	2.2	1.4	2.9	3.1	NS	2.4	2.0	NS	3.0	1.7	2.4
C.V.%	5.7	3.6	3.5	7.5	7.7	5.6	6.0	7.0	6.4	5.1	7.8	4.7	5.1	6.2	9.9	6.7	6.2	7.6

The FYM rates viz., 5, 10 and 15 t/ha did not influence the germination count in 1982-83 but during latter two years it was seen that a higher rate of FYM (15 t/ha) hastened the germination. It differed significantly from 5 t/ha FYM but remained at par with 10 t/ha FYM rate. The lower two rates in turn did not differ significantly from each other.

In case of methods of application of FYM, the surface application of FYM (M_2) hastened germination and was significantly superior to the FYM incorporated into the soil (M_1).

None of the interactions influenced the days taken to completion of germination except in 1983-84 where seed rate x methods of application of FYM (S x M) was found to be significant and has been presented in Appendix XXII.

4.1.2. Number of shoots

The data on the number of shoots per metre row length recorded at various stages of crop growth and at harvest have been presented in Table 5 and depicted graphically in Fig.3. The corresponding analyses of variance have been presented in Appendix II.

The number of shoots increased upto 10 WAS and decreased thereafter consistently till harvest during all the 3 years of experimentation (Fig. 3). During the first year, it was observed that at each stage of growth viz., 6, 8, 10, 12 WAS and at harvest, the number of shoots increased significantly with the increase in seed rates. During rest of the two years also a higher shoot number was observed at a higher seed rate (Fig.3) but the difference was not significant between S_1 and S_2 at 8 WAS and between S_2 and S_3 at 6 and 10 WAS during 1983-84. Similarly, the difference was not significant between S_1 and S_2 at 6, 8 and 12 WAS and between S_2 and S_3 at 10 and 12 WAS and at harvest during 1984-85.

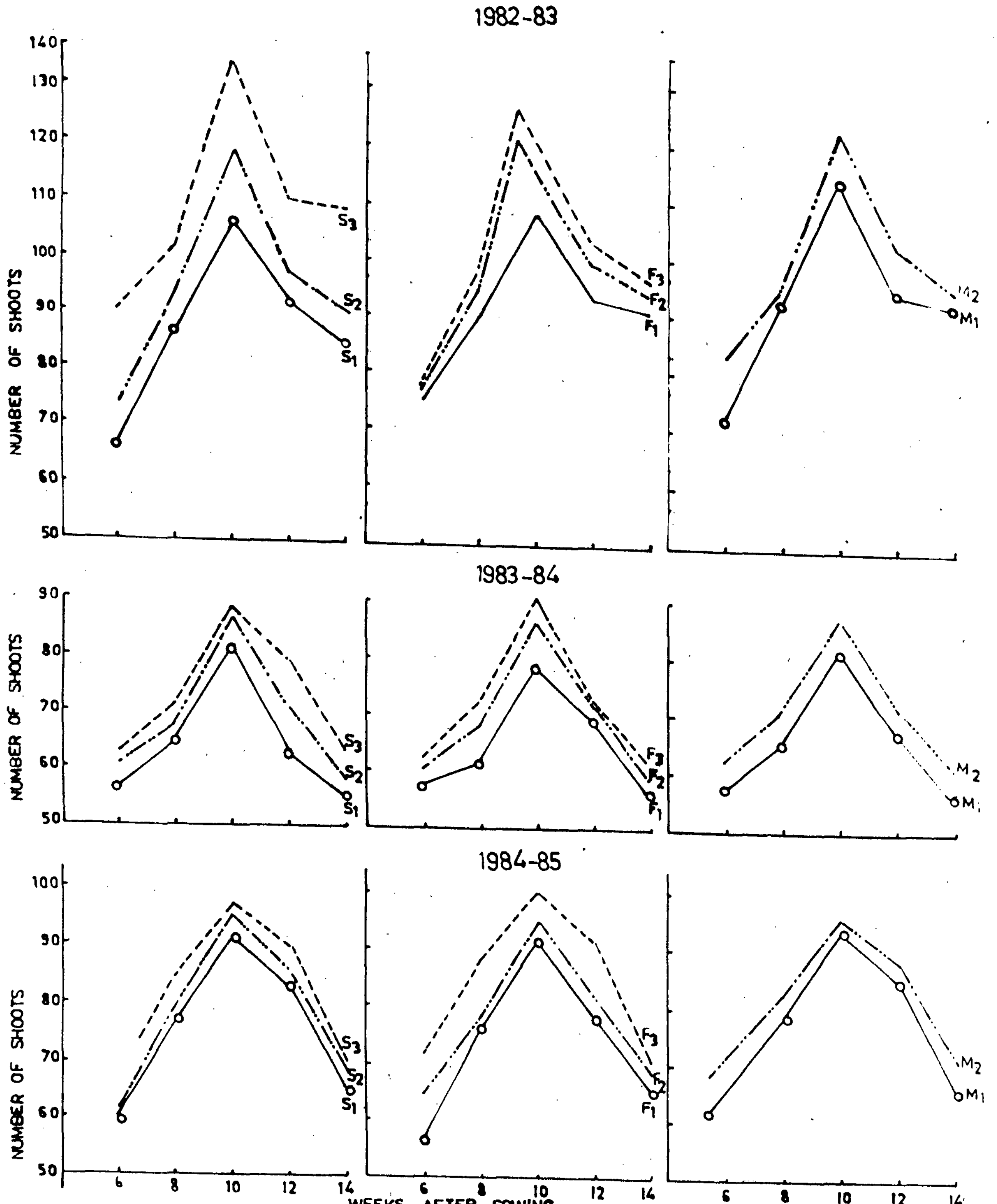

FIG. 3 TREATMENT EFFECTS ON NUMBER OF SHOOTS PER METRE

During the first year of experimentation the FYM rates did not influence the shoot number at 6 WAS but at rest of the stages on increase in FYM rates resulted in an increase in shoot number where 10 t/ha FYM resulted in significantly higher shoot number as compared to 5 t/ha, at all the stages of growth, the difference between 15 t and 10 t/ha was found to be significant only at 10 and 12 WAS. More or less a similar trend was observed during 2nd and 3rd year of experimentation also. A higher rate of FYM resulted in higher shoot number but the two consecutive FYM rates did not differ significantly at some of the growth stages.

Surface application of FYM was found to be superior to incorporation of FYM in the soil for the number of shoots per metre row length at all the stages of growth except that the difference was not significant at harvest in 1982-83 and at 10 and 12 WAS in 1984-85.

Interaction effect of seed rates x FYM levels (S x F) which was found to influence the number of shoots per metre row length significantly at least for two years during the course of investigation at different stages of growth has been presented in Tables 5.1a to 5.1d.

The interaction effect data presented in Table 5.1a show that at 6 WAS during both the years (1983-84 and 1984-85) almost at each FYM rate a higher seed rate recorded a higher shoot number per metre row length except that at F_2 level

Table 5.1a. Effect of S x F interaction on number of shoots m^{-1} row length at 6 WAS (1983-84 and 1984-85)

Seed rates	1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	53.7	56.4	59.2	53.0	58.0	68.1
S_2	56.3	66.7	58.9	54.9	60.1	69.1
S_3	61.7	58.7	67.2	70.9	75.2	75.0
SEm±		1.7			1.3	
CD5%		5.3			4.2	

in 1983-84, S_2 recorded a higher shoot number as compared to S_3 and difference was also significant. Only at this level of FYM, S_2 recorded significantly higher shoot number as compared to S_1 whereas at rest of the levels during both the years, S_1 and S_2 were found to be at par with each other. S_3, however, maintained its superiority statistically also. In 1983-84, S_3F_3 recorded the highest shoot number which remained at par with S_2F_2 but differed significantly from rest of the S x F treatment combinations. In 1984-85, though S_3F_2 treatment combination recorded highest shoot number and differed significant from rest of the treatment combinations but recorded almost similar number of shoots when compared with S_3F_3.

At 8 WAS the seed rates x FYM levels interaction effect was found to be significant during all the 3 years of experimentation. The interaction effect data presented in Table 5.1b show that during all the 3 years of experimentation at each level of FYM an increase in seed rate resulted in an increase in shoot number except at F_2 during 1983-84 and 1984-85. The increase was found to be significant only upto S_2 seed rate and at F_3 during 1982-83 and 1984-85 the differences were not significant.

Table 5.1b. Effect of S x F interaction on number of shoots m^{-1} row length at 8 WAS (1982-83, 1983-84 and 1984-85)

Seed rates	1982-83			1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	75.5	84.9	98.5	56.5	66.2	70.3	78.6	69.8	84.1
S_2	85.9	97.4	97.7	59.5	80.0	64.5	68.2	82.7	86.8
S_3	107.2	102.7	96.2	68.3	60.6	83.9	84.8	79.6	88.5
SEm±		1.1			2.0			2.0	
CD5%		6.6			5.6			6.0	

Contrary to this the effect of FYM levels at a fixed rate was not consistent over years. At S_1 in 1982-83, the increase in shoot number was noticed upto F_3 level whereas in 1983-84 it was only upto F_2 level. In 1984-85 there was even a decrease in shoot number as the FYM level was increased from F_1 to F_2. At S_2 the increase was significant only upto F_2 level during all the 3 years of experimentation. Contrary to this, in 1982-83 at S_3, F_1 recorded the highest number of shoots per metre row length whereas in 1983-84 and 1984-85 F_3 recorded the highest number.

At 10 WAS also, S x F interaction effect influenced the shoot number during all the three years of experimentation. The interaction effect data presented in Table 5.1c show that during first and third year an increase in seed rate resulted in corresponding increase in the shoot number. Only at F_3 level in 1984-85, the seed rates did not differ significantly. During 2nd year of experimentation the increase in shoot number was seen only upto S_2.

Table 5.1c. Effect of S x F interaction on number of shoots m^{-1} row length at 10 WAS (1982-83, 1983-84 and 1984-85)

Seed rates	1982-83			1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	93.5	107.3	118.6	74.9	80.7	85.5	90.4	88.6	96.3
S_2	113.1	115.3	129.0	83.5	84.9	94.0	84.7	99.6	100.1
S_3	119.5	141.6	130.5	77.5	93.0	93.3	96.6	94.6	100.2
SEm±		2.3			1.8			1.7	
CD5%		7.1			7.7			5.2	

While seeing the effect of FYM levels at a fixed seed rate it was observed that an increase in FYM level under all the seed rates an increased number of shoots and particularly F_3(15 t/ha) level of FYM was significantly superior to F_1 (5 t/ha FYM).

At 12 WAS, the interaction effect was found to influence the shoot number only in 1982-83 and 1983-84 (Table 5.1d). During both the years the highest seed rate of 150 kg/ha resulted in an increased number of shoots except that at F_3 in 1983-84 where it was at par with S_2. While seeing the effect of FYM at varying seed rates it was observed that at S_3, FYM levels had no effect on shoot number but at lower seed rates the shoot number increased with an increase in FYM levels.

Table 5.1d. Effect of S x F interaction on number of shoots m^{-1} row length at 12 WAS (1982-83 and 1983-84).

Seed rates	1982-83			1983-84		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	84.0	91.1	94.0	65.0	64.2	59.5
S_2	87.2	98.8	105.9	61.2	63.5	78.5
S_3	106.5	109.5	110.3	81.1	77.1	78.2
SEm±		1.9			2.5	
CD5%		5.8			5.0	

At harvest, the interaction effect was found to be significant during all the 3 years of experimentation (Table 5.1e). During first year of experimentation an increase in seed rates resulted in corresponding increase in shoot number. During 3rd year also more or less similar trend was observed but at F_3 the trend was just the reverse. In 1983-84 also, at F_2 level of FYM the trend was similar to that at F_3 in 1984-85.

While seeing the effect of FYM levels at different seed rates it was seen that FYM levels did not influence the shoot number significantly particularly at S_3. At lower seed rates also the effect of FYM was either not significant or the FYM levels had to be increased ot its highest level of 15 t/ha to have visible eff

Table 5.1e. Effect of S x F interaction on number of shoots m^{-1} row length at harvest (1982-83, 1983-84 and 1984-85)

Seed rates	1982-83			1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	82.1	85.9	85.5	50.2	61.3	56.0	61.6	63.2	72.8
S_2	79.4	93.1	96.7	55.5	53.0	65.5	66.3	71.0	66.2
S_3	108.2	106.6	102.9	63.0	60.9	65.2	68.0	72.3	69.5
SEm±		2.4			1.4			1.9	
CD5%		7.3			4.2			5.9	

The interaction effect of seed rates x methods of FYM application(S x M) influenced the number of shoots per metre row length during all the 3 years of experimentation at 6 WAS, in 1982-83 and 1983-84 at 12 WAS and in 1983-84 and 1984-85 at harvest. The interaction effect data at different stages have been presented in Table 5.2a, 5.2b and 5.2c, respectively.

The interaction effect data presented in Table 5.2a reveal that with the exception of M_2 in 1983-84 an increase in seed rates resulted in more number of shoots per metre row length during all the 3 years of experimentation. However, for a significant increase in the seed rates had to be increased to its highest level of 150 kg/ha .

Table 5.2a. Effect of S x M interaction on number of shoots m^{-1} length at 6 WAS (1982-83, 1983-84 and 1984-85)

Seed rates	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
S_1	67.5	62.5	51.9	61.1	58.5	60.5
S_2	68.4	78.1	56.2	64.5	60.5	62.7
S_3	82.6	94.4	63.6	62.0	65.9	81.5
SEm±	1.6		1.3		1.0	
CD5%	4.6		3.8		2.9	

While seeing the effect of methods of FYM application it was seen that the effect was not consistent at different seed rates during all the 3 years of experimentation. It was seen that in 1982-83 as well as in 1984-85, S_3M_2 resulted in highest number of shoots which differed significantly from rest of the treatment combinations. In 1983-84 though S_2M_2 resulted in highest shoot number but it was at par with S_3M_2.

At 12 WAS where the interaction effect was found to be significant only during first two years of experimentation (Table 5.2b) it was seen that like that at 6 WAS at this stage also a higher seed rate resulted in more number of shoots but to have a consistently higher shoot number the seed rate had to be increased at 150 kg/ha (S_3). At each seed rate though the surface application of FYM (M_2) resulted in higher shoot number during both the years but the effect was significant only at S_2 and S_3 in 1982-83 and at S_1 in 1983-84.

Table 5.2b. Effect of S x M interaction on number of shoots m^{-1} row length at 12 WAS (1982-83 and 1983-84)

Seed rates	1982-83		1983-84	
	M_1	M_2	M_1	M_2
S_1	89.5	90.6	57.6	68.2
S_2	93.0	100.5	65.7	69.1
S_3	102.5	115.9	78.9	79.4
SEm±	1.4		1.2	
CD5%	4.1		3.5	

S x M interaction at harvest in 1982-83 and 1984-85 presented in Table 5.2c influenced significantly the number of shoots. It shows that in both the years at S_3, M_2 recorded the highest number of shoots but in 1982-83 at M_2, S_3 differed significantly from S_1 and S_2. The latter two remained at par with each other.

Table 5.2c. Effect of S x M interaction on number of shoots m^{-1} row length at harvest (1982-83 and 1984-85)

Seed rates	1982-83		1984-85	
	M_1	M_2	M_1	M_2
S_1	84.0	84.7	81.0	85.9
S_2	90.2	89.0	83.0	88.0
S_3	104.0	112.9	89.5	88.9
SEm±	1.8		1.4	
CD5%	5.2		4.2	

While comparing the methods M_1 and M_2 in 1982-83 it was seen that at S_3, M_2 recorded the highest number of shoots and differed significantly from M_1. Similar trend was also observed in 1984-85 at S_1 and S_2 where M_2 recorded more number of shoots which differed significantly from M_1.

FYM levels x Methods of FYM, application (F x M) interaction influenced the number of shoots significantly during all the 3 years at 6 and 10 WAS and at harvest and have been presented in Table 5.3a, 5.3b and 5.3c, respectively.

The interaction effect data at 6 WAS presented in Table 5.3a show that except for M_1 in 1982-83 the highest level of FYM (15 t/ha) resulted in highest number of shoots and the difference was significant from that of F_2 in 1984-85.

Table 5.3a. Effect of F x M interaction on number of shoots m^{-1} row length at 6 WAS (1982-83, 1983-84 and 1984-85)

FYM levels	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
F_1	77.8	71.1	56.9	57.6	59.0	60.1
F_2	70.3	81.7	56.7	63.8	58.9	69.2
F_3	70.4	84.2	58.1	66.3	67.0	75.4
SEm±	1.6		1.3		1.0	
CD5%	4.6		3.8		2.9	

At each level, the effect of methods of application of FYM was more conspicuous only at F_1 in 1982-83, M_2 did not show its superiority. Otherwise, during all the 3 years this method proved to be superior to M_1 and with the exception at F_1 in 1983-84 the differences were significant also.

At 10 WAS the F x M interaction significantly influenced the number of shoots (Table 5.3b) with both the methods F_3 resulted in highest shoot number during all the 3 years of experimentation and differed significantly from F_1. With F_2 the difference was significant only when the FYM was incorporated into the soil (M_1) during all the 3 years of experimentation. With the exception of F_3 in 1984-85 the surface application of FYM (M_2) resulted in higher number of shoots m^{-1} row length during all the 3 years of experimentation. At F_1, however, the difference was not significant but at rest of the levels, M_2 proved to be significantly superior to M_1.

Table 5.3b. Effect of F x M interaction on number of shoots m^{-1} row length at 10 WAS (1982-83, 1983-84 and 1984-85)

FYM levels	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
F_1	107.5	109.4	76.8	81.0	89.0	92.0
F_2	113.8	128.7	80.0	92.6	90.8	97.6
F_3	121.6	131.2	91.5	89.8	100.9	97.3
SEm±	1.7		1.9		1.3	
CD5%	5.0		5.5		3.6	

The F x M interaction significantly affected the number of shoots at harvest during the 3 years (Table 5.3c). At harvest also higher level of FYM tended to retain higher number of shoots per metre row length. Here, however, the effect was more conspicuous at medium level of FYM. As far as the methods of FYM application are concerned except for lower level (F_1) in 1982-83 and 1984-85, the surface application (M_2) showed its superiority over the incorporation method(M_1) at all the levels during the course of this investigation.

Table 5.3c. Effect of F x M on number of shoots m^{-1} row length at harvest (1982-83, 1983-84 and 1984-85)

FYM levels	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
F_1	95.5	85.8	54.9	57.0	68.4	62.2
F_2	91.8	98.0	55.5	62.2	59.5	78.0
F_3	90.0	102.8	58.5	65.7	67.9	71.5
SEm±	1.8		1.0		1.4	
CD5%	5.2		3.0		4.2	

The interaction effect of seed rate x FYM levels x methods of application of FYM (S x F x M) was significant at 6 WAS in 1982-83 and 1983-84, at 12 WAS in 1982-83 and 1984-85 and at harvest during all the 3 years of experimentation. The data have been presented in Tables 5.4a, 5.4b and 5.4c, respectively.

S x F x M interaction that influenced the shoot number m^{-1} at 6 WAS in 1982-83 and 1983-84 and has been presented in Table 5.4a shows that F x M combinations at varying seed rates did not have a particular trend of their effect on number of shoots. However, in 1982-83 at F_3M_2, S_3 resulted in the higher number of shoots and each seed rate differed significantly to one another. At the same treatment, in 1983-84, higher number of shoots were recorded but it did not differ significantly from S_1 and S_2.

The lowest number of shoots in 1982-83 was observed at $S_1F_2M_2$ and that in 1983-84 was observed at $S_1F_2M_1$.

Table 5.4a. Effect of S x F x M interaction on number of shoots m^{-1} row length at 6 WAS (1982-83 and 1983-84)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	70.7	62.5	69.2	61.0	60.7	66.0
S_2	71.7	61.7	71.7	66.5	88.7	79.2
S_3	91.0	86.7	70.2	86.0	95.7	107.5
SEm±			3.6			
CD5%			10.0			
			1983-84			
S_1	52.0	49.7	54.0	55.5	62.5	65.5
S_2	58.2	58.7	51.7	53.7	73.5	66.5
S_3	60.5	61.7	68.7	63.7	55.5	67.0
SEm±			2.9			
CD5%			8.1			

S x F x M interaction influenced the number of shoots m^{-1} row length at 12 WAS in 1982-83 and 1984-85. The interaction effect presented in Table 5.4b show that in 1982-83 at F_3M_2, S_3 recorded the highest number of shoots which differed significantly from S_1 and S_2. The latter two seed rates,however, remained at par with each other. The same trend was also observed at F_1M_1 and F_2M_1. At F_1M_2 and F_2M_2 each increase in seed rate resulted in a significant increase. More or less a similar trend was observed at F_2M_1 and F_1M_2 in 1984-85. At rest of F x M combinations the seed rates did not differ significantly.

In 1982-83 $S_3F_3M_2$ treatment combination resulted in highest shoot number per metre row length which differed significantly from rest of the treatment combination. In 1984-85, however, $S_3F_2M_1$ resulted in highest shoot number but it remained at par with $S_3F_3M_2$.

Table 5.4b. Effect of S x F x M interaction on number of shoots m^{-1} row length at 12 WAS (1982-83 and 1984-85)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	91.5	89.5	87.7	78.7	93.0	100.2
S_2	86.2	88.5	104.2	88.0	107.7	106.0
S_3	106.2	106.5	94.0	108.2	112.7	126.7
SEm±			3.2			
CD5%			8.9			
			1984-85			
S_1	77.7	77.5	87.7	71.7	91.5	94.5
S_2	76.5	84.2	88.5	80.5	90.2	93.5
S_3	81.2	100.0	87.5	97.7	69.5	99.5
SEm±			5.4			
CD5%			15.0			

S x F x M interaction at harvest in 1982-83, 1983-84 and 1984-85 influenced the shoot number m^{-1} running row length significantly. The data presented in Table 5.4c show that during all the 3 years at each method and rate of FYM application increase in seed rate resulted in corresponding increase in shoot number and S_3 differed significantly from S_1. However, at F_3M_1 and F_2M_2, in 1982-83 and in 1984-85, S_2 recorded highest number of shoots, which remained at par with S_3.

In 1982-83, $S_3F_3M_2$ resulted in highest shoot number and was found to be at par onlywwith $S_3F_1M_1$. On the other hand in 1983-84 though $S_2F_3M_2$ resulted in highest number of shoots but it was found to be at par with $S_3F_3M_2$. Contrary to this in 1984-85 $S_2F_2M_2$ resulted in highest shoot number and differed significantl from $S_3F_3M_2$.

Table 5.4c. Effect of S x F x M interaction on number of shoots m^{-1} at harvest (1982-83, 1983-84 and 1984-85)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	88.0	87.2	76.7	77.5	83.7	93.0
S_2	85.5	84.2	101.0	74.7	101.2	91.2
S_3	113.2	104.0	95.0	105.2	109.2	124.2
SEm±			4.0			
CD5%			11.2			
			1983-84			
S_1	51.7	56.7	52.2	47.5	66.2	59.0
S_2	53.7	49.5	60.0	57.0	57.7	71.0
S_3	59.2	60.5	63.5	66.7	62.7	67.2
SEm±			2.3			
CD5%			6.5			
			1984-85			
S_1	62.7	60.0	68.2	59.7	65.5	77.0
S_2	67.0	54.2	69.5	66.7	88.7	64.5
S_3	75.5	64.2	66.0	60.2	79.7	73.0
SEm±			3.2			
CD5%			9.0			

Some of the interactions viz., S x M at 8 and 10 WAS 1984-85, F x M at 8 and 12 WAS in 1982-83 and S x F x M at 8 WAS in 1984-85 which influenced the shoot number only for single year have been given in Appendix XXII, XXIII and XXV, respectively.

4.1.3. Plant height

The influence of main effects on the plant height (cm) during 3 years of the study at different stages have been presented in Table 6 and the corresponding analyses of variance given in Appendix III. The pattern of changes in the plant heights at different stages of growth has also been depicted graphically in Fig.4.

An examination of Table 6 and Fig.4 indicates that the plant height increased between 9 and 15 WAS due to seed rates, FYM levels and methods of FYM application at a faster rate. The rate of increase after 15 WAS was slowed down.

During first year, at 6 WAS and at harvest, the plant height was not influenced by seed rates. During 3rd year also the plant height was neither influenced at 6 WAS nor at 9, 12 and 18 WAS. At rest of the stages it was seen that the lower seed rate (S_1) resulted in taller plants and with few exceptions differed significantly with S_2. The higher seed rates (S_2 and S_3) generally resulted in plants with identical heights.

The application of FYM did not influence the plant height at 6 WAS in 1982-83, at 6 and 12 WAS in 1983-84 and at 9 WAS in 1984-85. At rest of the stages during all the 3 years of experimentation it was seen that the plant height increased with increase in FYM levels. The difference between 5 and 10 t/ha was not significant consistently over the 3 years but 15 t/ha invariably proved its superiority over 5 or 10 t/ha level.

Surface application of FYM (M_2) resulted in taller plants and with the exception of that at 9 WAS in 1983-84 and at 6, 9, 12 and 15 WAS in 1984-85 the difference was significant.

Table 6. Treatment effects on plant height (cm) at various stages of crop growth

Treatments	Weeks after sowing (WAS)																	
	6			9			12			15			18			At harvest		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rate (kg/ha																		
100	8.5	5.6	12.9	14.7	12.6	35.1	39.0	38.5	53.0	64.4	49.9	55.8	67.4	52.8	56.8	72.2	55.0	58.5
125	8.5	5.6	12.6	14.1	12.3	32.2	37.2	38.2	52.0	63.2	48.0	53.3	64.4	50.9	55.6	71.6	53.8	56.6
150	8.2	5.2	12.2	13.3	11.2	31.6	36.7	34.6	51.1	62.3	45.7	53.0	63.0	50.2	55.6	71.3	52.4	56.0
SEm±	0.1	0.1	0.2	0.1	0.2	1.2	0.6	0.4	1.2	0.4	0.4	0.7	0.5	0.5	0.6	0.5	0.6	0.6
C.D.5%	NS	0.2	NS	0.3	0.5	NS	1.7	1.3	NS	1.3	1.1	2.1	1.6	1.5	NS	NS	1.9	1.8
B. FYM rates (t/ha)																		
5	8.3	5.4	11.3	13.2	11.4	31.2	35.2	36.8	49.5	61.5	44.9	51.7	61.8	49.2	53.6	69.5	53.3	54.8
10	8.3	5.5	12.5	13.9	12.2	32.5	35.8	37.0	51.6	62.4	48.4	53.7	64.8	51.6	56.7	71.4	53.8	57.7
15	8.6	5.6	13.8	15.1	12.5	35.1	41.9	37.6	55.0	66.0	50.3	56.7	68.1	53.2	57.7	74.3	55.0	58.6
SEm±	0.1	0.1	0.2	0.1	0.2	1.2	0.6	0.4	1.2	0.4	0.4	0.7	0.5	0.5	0.6	0.5	0.6	0.6
C.D.5%	NS	NS	0.7	0.3	0.5	NS	1.7	NS	3.6	1.3	1.1	2.1	1.6	1.5	1.9	1.6	1.9	1.8
C. Application methods																		
Incorporation	8.2	5.2	12.5	13.9	12.1	32.9	36.8	36.3	51.1	62.3	46.3	53.3	63.8	50.6	54.7	70.1	52.6	55.5
surface applied	8.5	5.7	12.6	14.2	12.0	33.1	38.4	37.9	53.0	64.3	49.5	54.8	66.1	52.0	57.3	73.3	54.8	58.6
SEm±	0.1	0.1	0.2	0.1	0.1	1.0	0.5	0.4	1.0	0.3	0.7	0.6	0.8	0.4	0.5	0.4	0.5	0.5
C.D.5%	0.2	0.2	NS	0.3	NS	NS	1.4	1.0	NS	1.1	0.9	NS	1.3	1.2	1.5	1.3	1.5	1.5
C.V.%	6.5	8.7	10.8	4.7	8.3	19.0	8.1	5.4	12.1	3.7	4.2	6.7	4.2	5.3	5.9	4.0	6.1	5.5

S x F interaction at 9 WAS in 1982-83 and 1983-84 (Table 6a), S x F interaction at 18 WAS in 1983-84 and 1984-85 (Table 6b), S x M interaction at 15 WAS in 1982-83 and 1983-84 (Table 6c) and F x M interaction at harvest in 1982-83 and 1984-85 (Table 6d) influenced the plant height significantly.

A perusal of data presented in Table 6a shows that by increasing the seed rates plant heights decreased at all the 3 levels of FYM. In 1982-83 at F_1, S_1 and in 1983-84 at $F_2 S_1$ recorded more plant height which remained at par with S_2 and differed significantly from S_3. In 1982-83 at F_2, S_1 and in 1983-84 at F_1, S_1 recorded the maximum plant height and each seed rate differed significantly to one another. In 1982-83 at F_3 each seed rate did not differ significantly but in 1983-84 at F_3, S_3 recorded the maximum plant height and differed significantly from S_1. However, S_2 remained at par with S_3. At fixed seed rates at S_1 and S_2 the FYM rates were not consistent, but in both the years at S_3, F_3 recorded the maximum plant height and each FYM rate differed significantly.

Table 6a. Effect of S x F interaction on plant height at 9 WAS (1982-83 and 1983-84)

Seed rates	1982-83			1983-84		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	13.8	15.2	15.3	13.2	12.4	11.9
S_2	13.6	13.8	14.9	11.2	13.5	12.7
S_3	12.0	12.8	15.2	9.6	10.9	13.2
SEm±		0.2			0.3	
CD5%		0.7			1.1	

S x F interaction influenced the plant height significantly at 18 WAS in 1983-84 and 1984-85. Interaction effect data presented in Table 6b. show that during both the years at all the levels of FYM, when the seed rates were increased

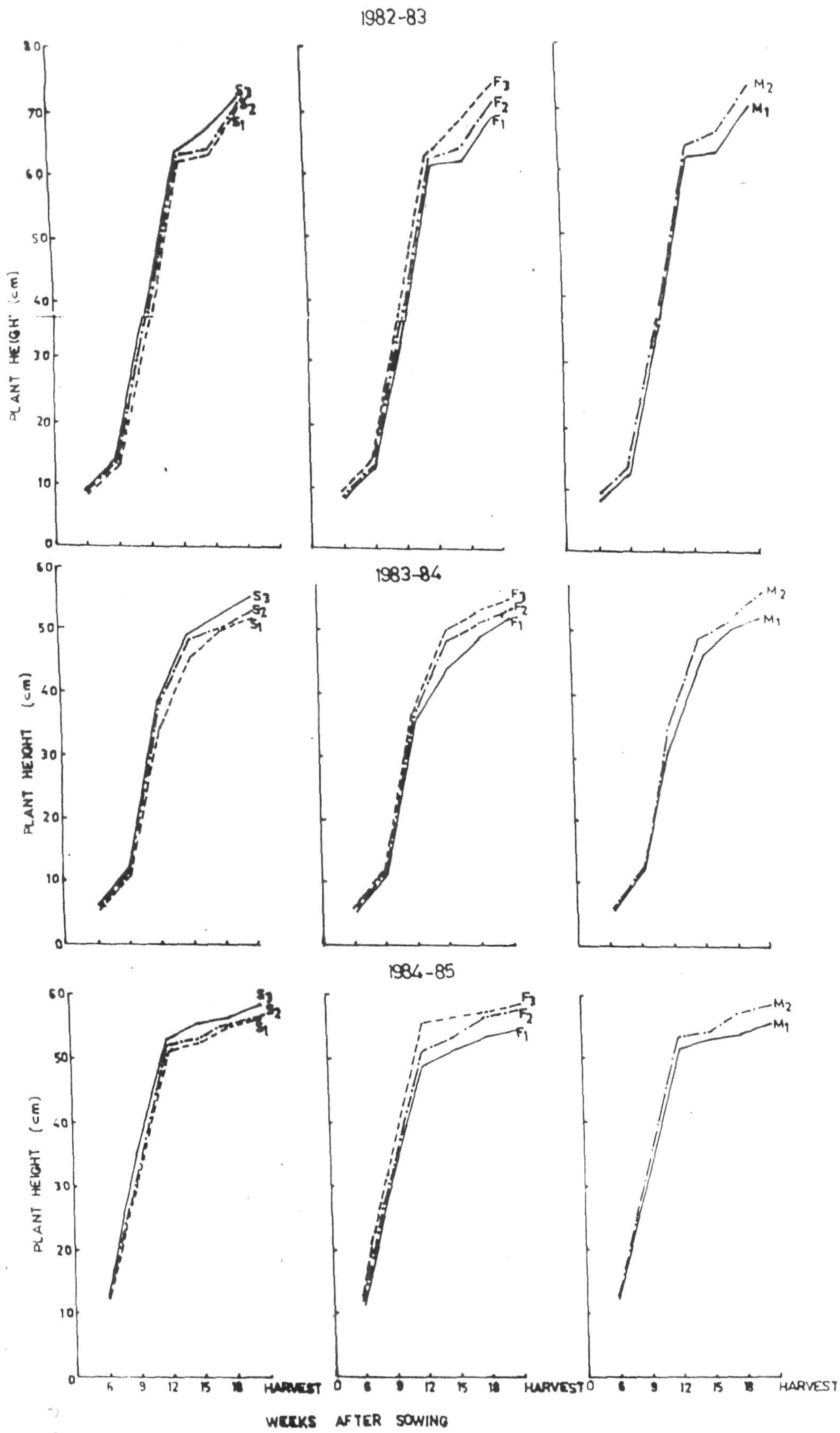

FIG. 4 TREATMENT EFFECTS ON PLANT HEIGHT

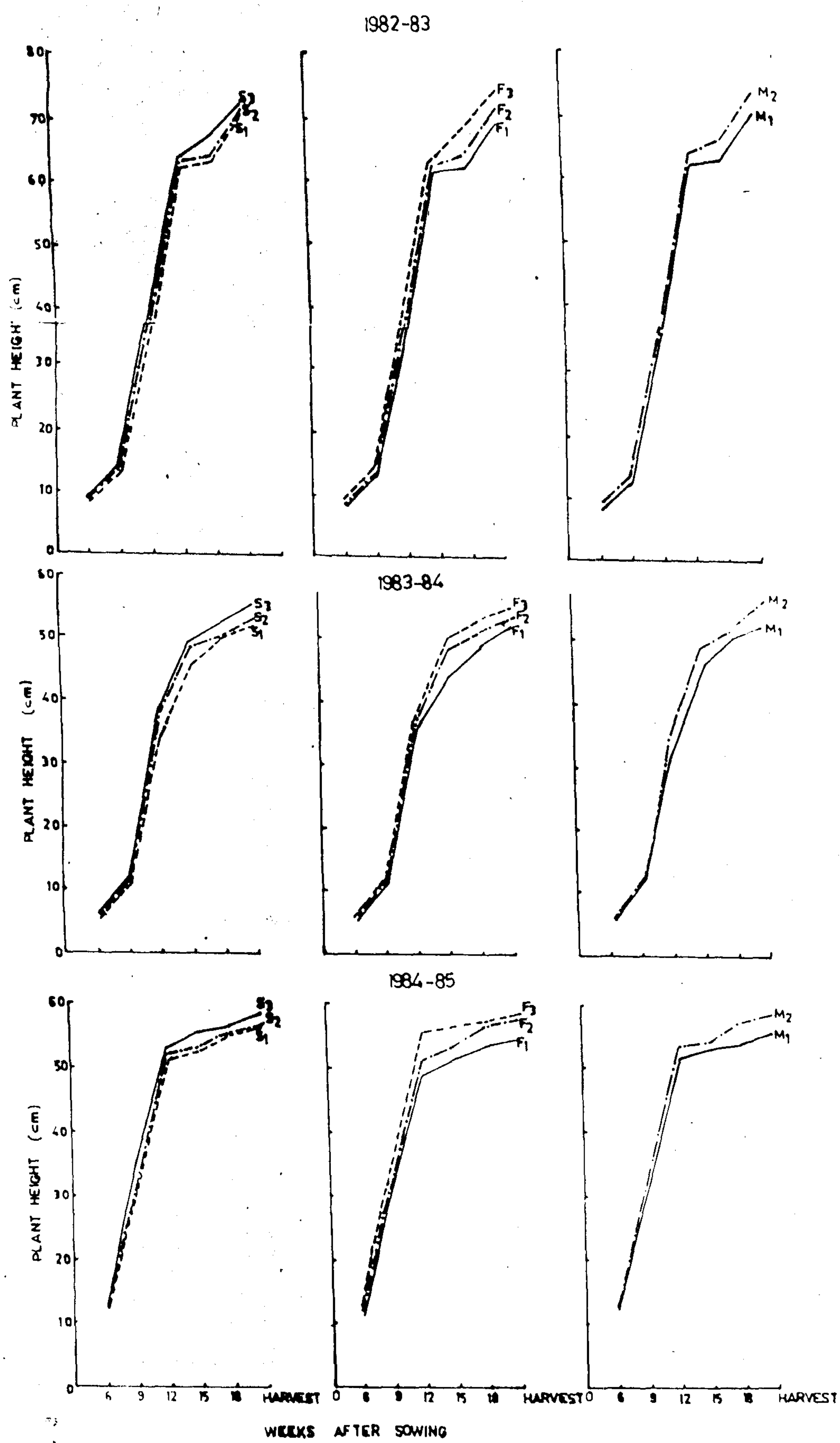

FIG. 4 TREATMENT EFFECTS ON PLANT HEIGHT

the plant heights decreased significantly. During 1983-84 S_1 resulted in maximum plant height at F_1 and F_3 and it was significantly higher than S_2. In 1984-85 also S_1 resulted in maximum plant height at F_3 and differed significantly from S_3. In 1983-84 at F_2, S_1 recorded the maximum plant height and differed significantly from S_3. However, S_2 remained at par with S_1 and S_3 but in 1984-85 at F_2, S_2 recorded more plant height which differed significantly from S_1 and S_3. These two were at par with each other. In 1984-85 F_1 and F_2 were not consistent in their effect at different levels of seed rates.

Table 6b. Effect of S x F interaction on plant height at 18 WAS (1983-84 and 1984-85)

Seed rates	1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	51.4	53.5	54.5	54.4	55.7	59.7
S_2	48.8	51.9	51.3	50.5	59.3	58.0
S_3	46.2	50.3	53.9	55.8	55.3	55.5
SEm±		1.0			1.2	
CD5%		3.1			3.8	

At fixed seed rates during both the years increase in FYM rates, resulted in an increase in plant height. At S_1 the results were not consistent but at S_2 during both the years, F_2 recorded more plant height and in 1983-84 it remained at par with F_1 and F_3 but in 1984-85, it remained at par with F_3 and differed significantly from F_1. In 1983-84 at S_3, F_3 recorded more plant height, each FYM rate differed significantly. However, during 1984-85 F_1 recorded maximum plant height and each FYM rate remained at par with one another.

S x M interaction at 15 WAS during 1982-83 and 1983-84 presented in Table 6c influenced the plant height significantly. It was observed that in both the years increasing the seed rates at both the methods decreased the plant height. In 1982-83 at M_1 and in 1983-84 at M_2, seed rate S_1 and S_2 remained at par with each other and differed significantly from S_3. In 1982-83 at M_2 and in 1983-84 at M_1, the maximum plant height was recorded at S_1, but it differed significantly from S_2 and S_3. The latter two were at par with each other. While comparing the methods (M_1 and M_2) at fixed seed rates it was seen that surface application of FYM (M_2) recorded more plant height and differed significantly from incorporation (M_1), except in 1982-83 at S_2 and S_1 in 1983-84 where both the methods were at par with each other.

Table 6c. Effect of S x M interaction on plant height at 15 WAS (1982-83 and 1983-84)

Seed rates	1982-83		1983-84	
	M_1	M_2	M_1	M_2
S_1	63.3	65.6	49.5	50.3
S_2	63.2	63.1	44.6	51.4
S_3	60.4	64.2	44.8	46.7
SEm±	0.6		0.5	
CD 5%	1.9		1.6	

F x M interaction at harvest presented in Table 6d indicated that increasing the FYM rates in both the years increased the plant height. In 1982-83, at M_1 and M_2 and in 1984-85 at M_1, F_3 recorded maximum plant height, which differed significantly from F_1. With M_1 during both the years the difference was significant even with F_2.

Table 6d. Effect of F x M interaction on plant height at harvest (1982-83 and 1984-85)

FYM levels	1982-83		1984-85	
	M_1	M_2	M_1	M_2
F_1	67.5	71.5	53.5	56.0
F_2	69.0	73.8	54.3	61.1
F_3	73.9	74.6	58.6	58.6
SEm±	0.8		0.9	
CD5%	2.3		2.6	

When the FYM application methods were compared at fixed FYM rates it was seen that in 1982-83 at all the levels of FYM and in 1984-85 only at F_2, M_2 recorded more plant height which differed significantly from M_1. In 1984-85, at F_1 and F_3, both the methods of application of FYM were at par with each other.

The single year interactions which influenced the plant height significantly viz., S x F interaction at 12 and 15 WAS in 1983-84, at harvest in 1984-85 (Appendix XX). S x M interaction at 6 WAS in 1982-83 at 9 and 12 WAS in 1983-84, at harvest in 1984-85 (Appendix XXII). S x F x M interaction at 6 WAS in 1982-83 at 9 WAS in 1983-84, at harvest in 1984-85 have been given in Appendix XXV.

4.1.4. Green matter production

The data on green matter accumulation (g/m^2) at different stages viz., 6, 10, 14, 18 WAS and at harvest during the growth period of crop as influenced by different treatments have been given in Table 7. The corresponding analyses of variance have been appended in Appendix IV.

An examination of data presented in Table 7 shows that during all the three years the green matter accumulation increased progressively at all the stages of growth upto 18 WAS and registered a decline at harvest.

Table 7. Treatment effects on green matter production (g/m^2) at various stages of crop growth.

Treatments	Weeks affter sowing (WAS)														
	6			10			14			18			At harvest		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)															
100	23.3	18.4	21.1	78.6	69.8	74.1	924.5	647.8	759.7	1055.5	813.6	904.8	604.4	461.2	510.0
125	27.2	22.8	25.2	98.7	83.5	91.0	1099.8	700.6	824.5	1097.4	863.1	954.6	648.7	524.9	587.5
150	28.2	24.3	27.3	97.1	86.4	93.3	984.9	763.7	849.7	1127.6	878.8	966.5	694.5	527.4	589.3
SEm±	0.2	0.3	0.2	0.9	0.6	0.5	72.1	5.1	9.5	[illegible].2	4.2	7.1	9.0	3.8	6.0
C.D.5%	0.7	0.8	0.6	2.8	2.0	1.6	NS	14.5	27.0	14.9	11.9	20.3	25.7	11.0	17.0
B. FYM rates (t/ha)															
5	25.2	19.6	22.7	84.7	73.8	80.8	951.8	668.5	788.3	1073.2	843.4	935.0	635.3	480.3	535.2
10	26.4	22.2	24.6	90.8	81.0	86.4	962.1	708.5	812.2	1092.6	847.2	940.9	643.7	504.7	560.6
15	27.1	23.6	26.3	94.8	84.9	91.2	1095.3	735.1	833.5	1114.0	864.9	950.0	668.7	528.4	590.9
SEm±	0.2	0.2	0.2	0.9	0.6	0.5	72.1	5.1	9.5	5.2	4.2	7.1	9.0	3.8	6.0
C.D.5%	0.7	0.8	0.6	2.8	1.9	1.6	NS	14.5	27.0	14.9	11.9	NS	25.7	11.0	17.0
C. Application methods															
Incorporation	25.5	20.5	23.4	85.8	75.6	82.7	1031.3	690.0	796.5	1076.7	838.6	931.6	627.0	489.1	545.4
Surface applied	26.9	23.1	25.7	94.4	84.2	89.5	974.8	718.1	826.1	1110.3	865.0	952.3	671.4	519.0	579.1
SEm±	0.2	0.2	0.1	0.7	0.5	0.4	58.9	4.1	7.7	4.2	3.4	5.8	7.4	3.1	4.9
C.D.5%	0.6	0.6	0.5	2.2	1.5	1.3	NS	11.8	22.1	12.2	9.7	16.6	21.0	9.0	13.9
C.V.%	4.8	5.9	4.5	5.2	4.2	3.3	35.2	3.5	5.7	2.3	2.4	3.7	6.8	3.7	5.2

As the seed rates increased the green matter accumulation also registered an increase and the difference between 100 and 125 kg/ha seed rate was significant. Only at some of the stages viz., 10 and 14 WAS in 1982-83, 14 and 18 WAS and at harvest in 1984-85 and at harvest in 1983-84 the differences between 125 and 150 kg seed rate/ha was not significant. Like seed rates the increase in FYM rates also resulted in an increase in green matter accumulation. 15 t/ha FYM resulted in highest green matter production at all the stages during all the 3 years of experimentation and differed significantly from 5 t/ha. The differences between 5 and 10 t/ha however, was not significant at 14 WAS and at harvest in 1982-83, at 18 WAS in 1983-84 and at 14 and 18 WAS in 1984-85. Also, the difference between 10 and 15 t/ha was not significant at 6 and 14 WAS and at harvest in 1982-83 and at 14 and 18 WAS in 1984-85.

In respect of methods of application of FYM it was interesting to note that surface application of FYM (M_2) always proved to be superior to incorporation (M_1) and the difference was significant at all the stages of growth during all the 3 years of investigations.

The first order of interaction effect of seed rate x FYM rate (S x F) at 6 WAS was found to influence the green matter production significantly during all the three years (Table 7.1a). It was noticed that F_1 and F_2 in 1982-83 and 1984-85 and at F_2 in 1983-84 each increase in seed resulted in a significant increase in green matter production. At rest of FYM rates during different years the increase was found to be significant only upto F_2 level.

At fixed seed rates in 1982-83 at S_1 and S_2, F_3 recorded the highest green matter production which differed significantly from F_1 and F_2. The latter two remained at par with each other. In 1983-84 and 1984-85 also at S_1, F_3 recorded the highest green matter which remained at par with F_2 and differed significantly from F_1. In 1982-83 at S_3, F_2 registered the highest green matter production which differed significantly from F_1 and F_3. The latter two remained at par with each other.

Table 7.1a. Effect of S x F interaction on green matter accumulation (g/m^2) at 6 WAS (1982-83, 1983-84 and 1984-85)

Seed rates	1982-83			1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	22.6	22.7	24.4	16.0	18.8	20.2	19.5	21.3	22.4
S_2	25.6	26.8	29.3	21.1	22.0	25.2	23.4	24.3	28.1
S_3	27.6	29.5	27.7	21.5	25.7	25.6	25.1	28.2	28.5
SEm±		0.5			0.5			0.4	
CD5%		1.4			1.5			1.2	

Exactly the same S x F interaction effect was noticed at 10 WAS in 1983-84 and 1984-85. The interaction effect presented in Table 7.1b shows that increase in seed rates resulted in an increase in green matter production. During both the years it was seen that at F_1 and F_2 each increase in seed rate resulted in corresponding significant increase in green matter. At F_3, however, the increase was noticed only upto S_2 level.

Table 7.1b. Effect of S x F interaction on green matter production at 10 WAS (1983-84 and 1984-85)

Seed rates	1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	61.3	70.9	76.5	65.5	74.2	82.5
S_2	77.7	83.0	90.2	86.4	89.5	97.0
S_3	82.5	88.8	88.0	91.0	94.3	94.9
SEm±		1.3			1.1	
CD5%		2.7			3.3	

At each seed rate it was also observed that increase in FYM rate resulted in an increase in green matter production. In 1983-84 at S_1 and S_2 and in 1984-85 at S_1, F_3 recorded the highest green matter which differed significantly from each FYM rate. At S_3, in 1983-84 as well as in 1984-85 F_2 and F_3 recorded statistically same green matter but differed significantly from F_1.

S x M interaction effect on green matter production at 6 and 10 WAS in 1983-84 and 1984-85 presented in Table 7.1c shows that at 6 WAS in both the years the increased seed rates at M_1 and M_2 and at 10 WAS in 1983-84 at M_2 and in 1984-85 at M_1, S_3 (150 kg seed rate) resulted in significantly higher green matter production, which differed significantly from S_1 and S_2 (100 and 125 kg seed rate/ha). At 10 WAS in 1983-84 at M_1 and in 1984-85 at M_2, S_3 recorded highest green matter which remained at par with S_2 and differed significantly from S_1.

Table 7.1c. Effect of S x M interaction on green matter production at 6 and 10WAS (1983-84 and 1984-85)

Seed rates	1983-84		1984-85	
	M_1	M_2	M_1	M_2
		6 WAS		
S_1	16.3	20.4	19.5	22.7
S_2	21.7	23.8	24.0	26.4
S_3	23.3	25.1	27.7	27.9
SEm±	0.3		0.3	
CD5%	1.0		0.9	
		10 WAS		
S_1	63.9	75.6	69.0	79.4
S_2	80.3	86.7	88.1	93.8
S_3	82.4	90.3	91.2	95.4
SEm±	0.9		0.8	
CD5%	2.7		2.3	

While comparing the methods of FYM application at fixed seed rate, except at 6 WAS in 1984-85 at S_3, these two methods differ significantly but in rest of the cases in both the years at 6 and 10 WAS at fixed seed rate M_2 recorded higher green matter production and was significantly superior to M_1.

S x M interaction at 18 WAS during 1983-84 and 1984-85 presented in Table 7.1d shows the similar trend as discussed at earlier stages in Table 7.1c. During 1983-84 at M_1 each increase in seed rate resulted in a significant increase in dry matter production. In 1983-84 at M_2 and in 1984-85 at M_1 and M_2, the increased seed rate , 150 kg/ha (S_3) resulted in higher green matter production which remained at par with S_2 and differed significantly from S_1. While comparing the methods of application of FYM in both the years at lower seed rate S_1, M_2 recorded higher green matter production which differed significantly from M_1. However, at medium and higher seed rates in both the years methods of FYM application (M_1 and M_2) did not differ significantly.

Table 7.1d. Effect of S x M interaction on green matter production (g/m^2) at 18 WAS (1983-84 and 1984-85)

Seed rates	1983-84		1984-85	
	M_1	M_2	M_1	M_2
S_1	782.7	844.4	881.3	928.4
S_2	855.2	871.1	944.6	964.6
S_3	878.0	879.5	969.0	964.0
SEm±	5.9		10.1	
CD5%	16.9		28.7	

In the year 1982-83 and 1983-84 the interaction effect of F x M influenced the green matter accumulation significantly (Table 7.1e). In both the years at each method increase in FYM rates resulted in a significant increase in green matter accumulation. At the sametime at each level surface application resulted in significantly higher green matter accumulation. During both the years F_3M_2 resulted in highest green matter accumulation, which differed significantly from rest of the treatment combinations.

Table 7.1e. Effect of F x M interaction on green matter production at 10 WAS (1982-83 and 1983-84)

FYM levels	1982-83		1983-84	
	M_1	M_2	M_1	M_2
F_1	83.0	86.5	71.5	76.1
F_2	85.6	96.0	75.1	86.8
F_3	88.8	100.8	80.1	89.7
SEm±	0.3		0.9	
CD5%	1.0		2.7	

At 18 WAS, F x M interaction influenced the green matter production significantly in 1982-83 and 1983-84. The interaction effect data presented in Table 7.1f show that in 1982-83 at M_1, increasing rates of FYM did not differ significantly. In 1983-84 at M_1, F_3 recorded higher green matter production and differed significantly from F_2.

In 1982-83 at M_2, each increase in FYM resulted in a significant increase in green matter production. In 1983-84 with the same method of FYM application the significant increase was noticed only upto F_2 level.

Table 7.1f. Effect of F x M interaction on green matter production at 18 WAS (1982-83 and 1983-84)

FYM levels	1982-83		1983-84	
	M_1	M_2	M_1	M_2
F_1	1072.8	1073.5	843.1	843.6
F_2	1077.8	1107.4	825.3	869.1
F_3	1079.4	1150.1	847.4	882.4
SEm±	7.4		5.9	
CD5%	21.1		17.0	

At fixed rate of FYM in both the years at F_1, the methods did not differ significantly but at both the higher rates at (F_2 and F_3), M_2 registered higher green matter production during both the years and it differed significantly from M_1.

The data on the effect of F x M interaction on green matter production at harvest in 1983-84 and 1984-85 presented in Table 7.1g show that in both the years at M_1, the difference between F_1 and F_2 was not significant but as the FYM rate was increased to F_3 the difference became significant. In both the years at M_2, however, the differences become significant even at lower FYM rate also. The increase in FYM rate from F_2 to F_3 did not increase the green matter accumulation significantly.

Table 7.1g. Effect of F x M interaction on green matter production (g/m^2) at harvest (1983-84 and 1984-85)

FYM levels	1983-84		1984-85	
	M_1	M_2	M_1	M_2
F_1	479.5	481.1	536.3	534.2
F_2	476.1	533.3	531.3	590.0
F_3	511.6	545.3	568.7	613.0
SEm±	5.5		8.5	
CD5%	15.6		24.1	

At fixed rate of FYM at F_1 during both the years the difference between two methods was not significant. At F_2 and F_3 during both the years the higher green matter accumulation was at M_2 which differed significantly from M_1.

The second order of interaction S x F x M influenced the green matter production significantly at 6 WAS in all the 3 crop seasons. Interaction effect data presented in Table 7.2a reveal that the effect of increasing seed rates was more pronounced in 1982-83 and 1984-85 with the exception of that at F_3M_1 and F_3M_2 in 1982-83 at each of the FYM combination during both the years the increase in seed rates resulted in significant increase in green matter production. At F_3M_1 and F_3M_2 the increase was only upto S_2 level. The seed rates did not differ significantly from one another in 1983-84. The highest green matter production in 1982-83 was obtained at $S_2F_3M_2$.

Table 7.2a. Effect of S x F x M interaction on green matter production (g/m^2) at 6 WAS (1982-83, 1983-84 and 1984-85)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	22.6	22.7	22.1	22.6	22.8	26.6
S_2	25.6	25.6	28.1	25.5	28.2	30.4
S_3	27.9	28.0	27.1	27.2	31.0	28.2
SEm±			0.7			
CD5%			2.2			
			1983-84			
S_1	13.1	17.5	18.4	19.0	20.3	21.9
S_2	20.5	21.4	23.2	21.7	22.8	27.0
S_3	21.6	24.2	24.3	21.5	27.3	26.6
SEm±			2.9			
CD5%			8.1			
			1984-85			
S_1	16.8	20.6	21.2	22.3	22.1	23.7
S_2	22.9	22.5	26.5	23.9	25.9	29.4
S_3	25.2	27.4	27.3	25.0	29.0	29.7
SEm±			0.7			
CD5%			1.9			

In 1984-85 though the highest green matter yield was obtained at $S_3F_3M_2$ but it remained at par with $S_2F_3M_2$. Incidently in 1983-84 though the highest green matter yield was obtained at $S_3F_2M_2$ but it also remained at par with $S_2F_3M_2$.

The interaction S x F x M influenced the green matter accumulation significantly at 10 WAS also in 1983-84 and 1984-85. The data presented in Table 7.2b reveal that at each method and FYM level an increase in seed rate resulted in an increase in green matter production during both the years.

During 1983-84 and 1984-85 $S_2F_3M_2$ resulted in highest green matter production which was at par with $S_3F_2M_2$ and $S_3F_3M_2$ and differed significantly from rest of S x F x M treatment combinations.

Table 7.2b. Effect of the S x F x M interaction on green matter production (g/m^2) at 10 WAS (1983-84 and 1984-85)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1983-84			
S_1	53.3	64.1	74.4	69.5	78.2	79.0
S_2	77.8	78.3	84.9	77.3	87.6	95.2
S_3	84.4	82.9	81.0	81.5	94.7	94.9
SEm$\pm$			4.2			
CD5%			11.0			
			1984-85			
S_1	58.4	71.1	77.2	72.5	78.1	87.5
S_2	85.2	86.5	92.8	87.2	93.4	100.9
S_3	91.6	90.1	91.9	89.9	99.2	97.2
SEm$\pm$			1.8			
CD5%			5.0			

Some of the single year first order interactions viz. F x M at 6 WAS in 1982-83, F x M at 14 WAS in 1984-85 have been presented in Appendix XXIII and second order interaction S x F x M at 18 WAS in 1982-83 and at harvest in 1983-84 were also found to be significant and have been presented in Appendix XXIX.

4.1.5. Dry matter production

The treatment effects on dry matter accumulation (g/m^2) at different stages of growth during 3 years have been given in Table 8. The corresponding analyses of variance for the 3 years have embodied in Appendix V. The data have also been presented graphically in Fig.5.

An examination of Fig.5 indicateds that during all the 3 years under all the treatments the dry matter accumulation was slow between 6 and 10 WAS, later on at 14 and 18 WAS the dry matter accumulation increased progressively. From 18 WAS onwards there wwas a decline in dry matter production.

A perusal of the data (Table 8) reveals that with the exception of that of 14 WAS in 1982-83, at 18 WAS and at harvest in 1984-85 and at harvest in 1983-84 each increase in seed rate brought a significant increase over its proceding seed rate.

Like seed rates the FYM levels also influenced the dry matter production significantly. It was at 18 WAS in 1984-85 that the differences between F_1 and F_2 and F_2 and F_3 was not significant. At harvest, in 1983-84 the difference between F_2 and F_3 also was not found to be significant. At rest of the stages during the entire course of this investigation each increase in the FYM rate brought a significant increase in dry matter production over its lower level.

Table 8. Treatment effects on dry matter production (g/m^2) at various stages of crop growth

Treatments	Weeks after sowing (WAS) 6			10			14			18			At harvest		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)															
100	4.6	3.4	4.4	19.4	15.9	19.0	340.7	230.5	299.2	497.5	370.8	443.6	466.2	318.2	362.7
125	5.5	4.4	5.3	23.9	19.3	23.8	363.5	249.8	329.1	522.7	395.0	470.5	501.3	354.9	424.9
150	5.9	4.7	6.0	24.5	20.2	24.4	368.0	272.1	341.3	542.2	402.1	477.1	543.5	362.3	429.0
SEm±	0.05	0.05	0.07	0.2	0.1	0.2	1.1	1.7	4.0	2.1	1.6	3.7	7.0	4.4	4.3
C.D.5%	0.1	0.1	0.2	0.6	0.4	0.5	3.1	4.8	11.4	6.1	4.6	10.6	20.0	12.7	12.4
B. FYM rates (t/ha)															
5	5.1	3.8	4.9	20.9	16.9	20.8	350.4	234.8	309.9	504.1	383.6	457.4	492.7	328.8	382.1
10	5.3	4.3	5.3	22.7	18.7	22.6	359.3	252.2	323.8	520.9	389.3	465.3	496.9	349.2	404.9
15	5.6	4.5	5.6	24.1	19.8	23.9	362.6	365.3	335.9	537.5	394.8	468.6	521.4	357.4	429.6
SEm±	0.05	0.05	0.07	0.2	0.1	0.2	1.1	1.7	4.0	2.1	1.6	3.7	7.0	4.4	4.3
C.D.5%	0.1	0.1	0.2	0.6	0.4	0.5	3.1	4.8	11.4	6.1	4.6	10.6	20.0	12.7	12.4
C. Application methods															
Incorporation	5.1	3.9	5.0	21.2	17.3	21.4	349.6	243.6	314.5	505.8	380.7	456.5	483.3	334.8	391.2
Surface applied	5.6	4.5	5.4	23.9	19.6	23.5	365.2	258.0	331.9	535.9	397.8	471.0	524.0	355.5	419.9
SEm±	0.04	0.04	0.06	0.2	0.1	0.1	0.9	1.3	3.2	1.7	1.3	3.0	5.7	3.6	3.5
C.D.5%	0.1	0.1	0.1	0.5	0.3	0.4	2.5	3.9	9.3	5.0	3.8	8.7	16.3	10.4	10.1
C.V.%	5.4	6.6	7.4	5.2	4.4	3.9	1.5	3.3	6.1	2.0	2.0	3.9	6.8	6.3	5.3

Surface application of FYM (M_2) was significantly superior to M_1 and produced higher dry matter per unit area during all the 3 years at all the stages of crop growth.

S x F interaction that affected the dry matter production at 10 WAS in 1983-84 and 1984-85 (Table 8.1a) shows that during both the years at each level of FYM, S_1 resulted in lowest dry matter production and differed significantly from S_3. On occasions the difference between S_2 and S_3, however, was not significant. Similarly at each seed rate, F_1 resulted in lowest dry matter production and differed significantly from F_3 during both the years. Each increase in FYM brought an increase in dry matter production. Only at S_2 in 1984-85 the difference between F_1 and F_2 and at S_3 in 1983-84 as well as in 1984-85 the difference between F_2 and F_3 was not significant.

Table 8.1a. Effect of S x F interaction on dry matter production (g/m^2) at 10 WAS (1983-84 and 1984-85)

Seed rates	1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	13.7	16.3	17.6	16.4	19.3	21.3
S_2	17.9	19.3	20.8	22.6	23.3	25.7
S_3	19.2	20.5	21.0	23.6	24.9	24.7
SEm±		0.3			0.3	
CD5%		0.9			1.0	

S x F interaction that also affected the dry matter production at 14 WAS in 1982-83 and 1983-84 and has been presented in Table 8.1b shows that increasing the seed rates increased the dry matter at all the levels of FYM. During 1983-84 at all the level of FYM and in 1982-83 at F_2, S_3 recorded more dry matter production which differed significantly with S_1 and S_2. At all the levels of FYM the lowest seed rate resulted in the lowest dry matter production.

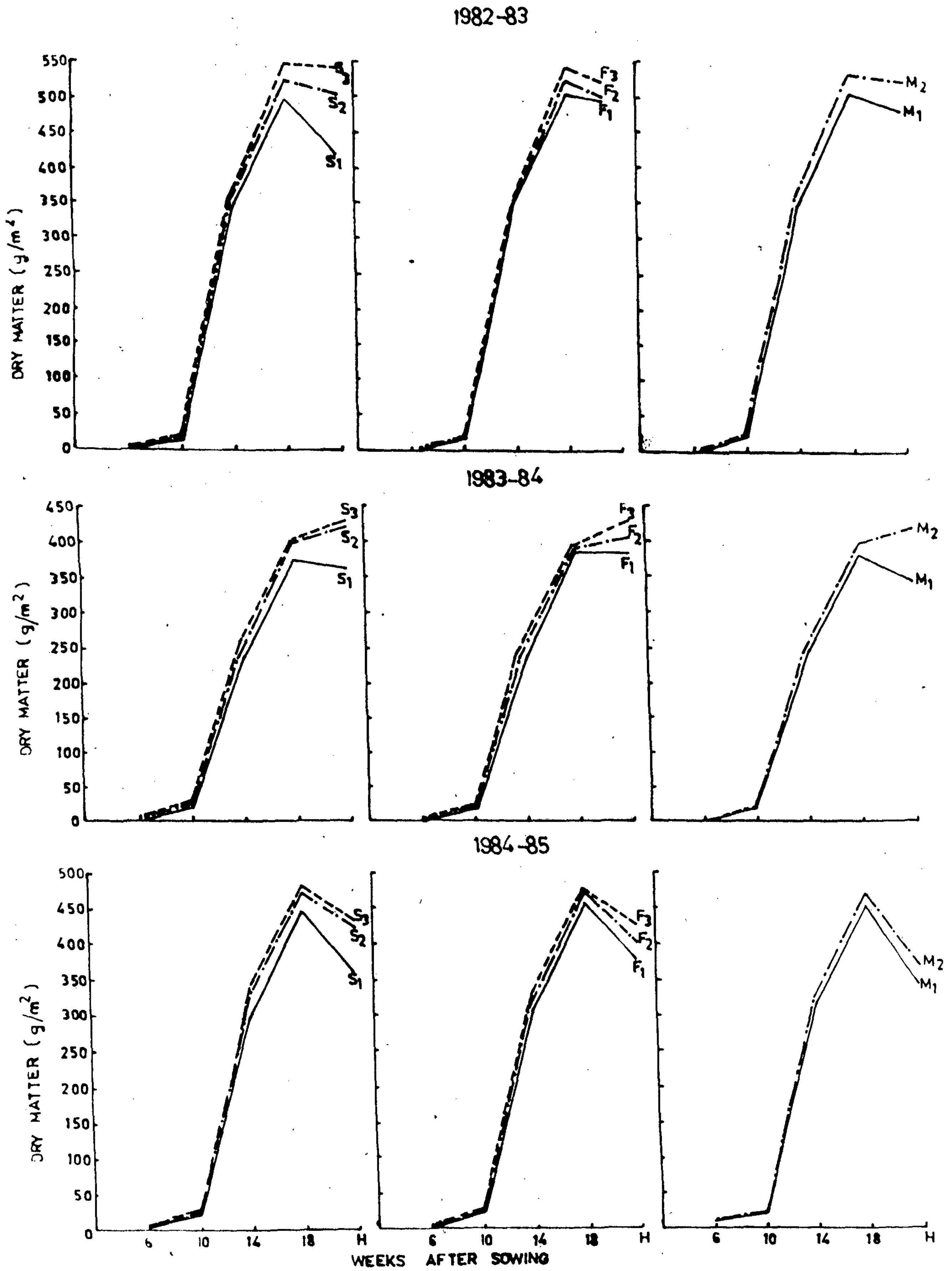

FIG. 5 TREATMENT EFFECTS ON DRY MATTER ACCUMULATION

Table 8.1b. Effect of S x F interaction on dry matter production (g/m^2) at 14 WAS (1982-83 and 1983-84)

Seed rates	1982-83			1983-84		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	331.0	340.0	350.7	216.0	227.3	245.4
S_2	359.5	364.0	366.6	239.8	250.6	260.8
S_3	360.1	372.2	372.8	250.6	278.3	288.2
SEm±		2.2			3.4	
CD5%		6.4			9.7	

At increased level of FYM at all the seed rates increased the dry matter production. In 1983-84, at all the seed rates and in 1982-83 at S_1, F_3 recorded more dry matter, which differed significantly from F_1 and F_2. During 1982-83 at S_2, F_3 differed significantly from F_1 but F_2 remained at par with F_1 and F_3. However, at S_3, F_3 remained at par with F_2 and differed significantly from F_1.

S x M interaction influenced the dry matter production significantly at 10 WAS in 1983-84 and 1984-85. The interaction effect data presented in Table 8.1c show that with each method of FYM application, S_1 resulted in lowest dry matter production during both the years and it differed significantly from S_2 and

Table 8.1c. Effect of S x M interaction on dry matter production (g/m^2) at 10 WAS (1983-84 and 1984-85)

Seed rates	1983-84		1984-85	
	M_1	M_2	M_1	M_2
S_1	14.4	17.4	17.5	20.5
S_2	18.5	20.5	22.9	24.7
S_3	19.0	21.4	23.7	25.2
SEm±	0.2		0.2	
CD5%	0.6		0.7	

S_3. The difference between S_2 and S_3 at M_1 in 1983-84 and at M_2 in 1984-85, however, was not significant. It was however, interesting to note that at each seed rate during both the years, M_2 resulted in significantly higher dry matter production over M_1.

F x M interaction effect significantly influenced the dry matter production at 10 WAS during all the 3 years of experimentation. The interaction affect data presented in Table 8.1d show that it was only at M_1 in 1982-83 when the FYM levels did not differ significantly from one another. Otherwise during rest of the years with each method, each increase in FYM level resulted in a significant increase in dry matter production. It was also interesting to note that during all the 3 years at each level of FYM, M_2 resulted in significantly higher dry matter production as compared to M_1.

Table 8.1d. Effect of F x M interaction on dry matter production (g/m^2) at 10 WAS (1982-83, 1983-84 and 1984-85)

FYM levels	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
F_1	20.3	21.6	16.4	17.6	20.1	21.5
F_2	21.3	24.3	17.3	20.2	21.4	23.8
F_3	22.2	26.1	18.4	21.2	22.7	25.2
SEm±	0.3		0.2		0.2	
CD5%	0.9		0.6		0.7	

F x M interaction also influenced the dry matter production significantly at 14 WAS (Table 8.1e). Like that at 10 WAS at this stage also it was seen that F_1 resulted in lowest dry matter production. The FYM levels however, did not differ significantly from one another at M_1 in 1984-85. The difference between F_2 and F_3 at M_1 in 1982-83 also was not significant.

Table 8.1e. Effect of F x M interaction on dry matter production (g/m^2) at 14 WAS (1982-83, 1983-84 and 1984-85)

FYM levels	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
F_1	346.4	354.3	232.5	237.1	308.3	311.5
F_2	351.7	366.8	243.7	260.7	314.0	333.5
F_3	350.7	374.4	254.6	276.1	321.1	350.7
SEm$\pm$	1.5		2.4		5.7	
CD5%	4.4		6.8		16.7	

Like that at 10 WAS at this stage also during all the 3 years at each level of FYM, M_2 resulted in higher dry matter production as compared to M_1, however, the difference was not significant at F_1 in 1983-84 as well as in 1984-85.

At 18 WAS, F x M interaction effect was found to be significant during the first two years, where it was seen that with each method of FYM application an increase in FYM resulted in a corresponding increase in dry matter production. Only at M_2 in 1983-84 an increase in FYM level from 10 to 15 t/ha did not result in a significant increase (Table 8.1f). Further, it was seen that only at lower level of FYM (F_1) the difference between M_1 and M_2 was not significant. At higher levels, M_2 always resulted in significantly higher dry matter production.

Table 8.1f. Effect of F x M interaction effect on dry matter accumulation (g/m^2) at 18 WAS (1982-83 and 1983-84)

FYM levels	1982-83		1983-84	
	M_1	M_2	M_1	M_2
F_1	499.9	508.3	382.2	385.1
F_2	505.6	536.1	374.5	404.2
F_3	511.8	563.2	385.4	404.3
SEm$\pm$	3.0		2.3	
CD5%	8.7		6.0	

At harvest, the interaction effect (F x M) was found to be significant in 1983-84 and 1984-85. The interaction effect data presented in Table 8.1g show that the effect of FYM levels did not remain so conspicuous till harvest in 1983-84. It was seen that only at M_2, the dry matter increased significantly and that too only upto F_2 level. In 1984-85, however, with each method of application an increase in FYM level resulted in a significant increase in dry matter production over its preceding level.

Table 8.1g. Effect of F x M interaction on dry matter accumulation (g/m^2) at harvest (1983-84 and 1984-85)

FYM levels	1983-84		1984-85	
	M_1	M_2	M_1	M_2
F_1	331.9	325.7	382.5	381.7
F_2	332.6	365.8	380.4	429.4
F_3	339.8	375.0	410.6	448.6
SEm±	6.3		6.2	
CD5%	18.0		17.6	

Like that at 18 WAS, at this stage also the differences between application methods were visible only at higher levels of FYM. At F_1 both the application methods were found to be at par with each other during both the years.

The 2nd order of interaction (S x F x M) influenced dry matter accumulation at 10 WAS significantly during all the 3 years of experimentation. The interaction effect data presented in Table 8.2a show that during all the 3 years with each method of application at different levels of FYM, the increase dry matter production was sharper when the seed rate was increased from S_1 to S_2. The increase from S_2 to S_3 did not influence the dry matter production so markedly.

It was interesting to note that $S_2F_3M_2$ resulted in higher dry matter production in 1984-85 and differed significantly from $S_3F_3M_2$. In 1982-83 and 1983-84 though $S_3F_3M_2$ resulted in highest dry matter production but it was at par with $S_2F_3M_2$.

Table 8.2a. Effect of S x F x M interaction on dry matter production (g/m^2) at 10 WAS (1982-83, 1983-84 and 1984-85)

Seed rates		M_1				M_2		
		F_1	F_2	F_3		F_1	F_2	F_3
					1982-83			
S_1		15.8	18.7	19.4		19.2	20.9	22.5
S_2		21.7	22.5	23.6		22.8	25.0	27.5
S_3		22.3	22.6	23.6		22.9	26.5	28.1
	SEm±				0.7			
	CD5%				2.0			
					1983-84			
S_1		11.7	14.6	17.0		15.9	18.0	18.2
S_2		17.9	18.2	19.5		17.9	20.4	22.2
S_3		19.4	19.0	18.7		18.9	22.0	23.2
	SEm±				0.5			
	CD5%				1.4			
					1984-85			
S_1		14.2	18.3	20.0		18.4	20.5	20.7
S_2		22.3	22.3	24.1		22.7	24.4	27.2
S_3		23.8	23.4	23.8		23.3	26.6	25.7
	SEm±				0.5			
	CD5%				1.5			

At 14 WAS, the interaction effect of seed rates x FYM levels x methods of application of FYM was found to be significant in 1982-83 and 1983-84 only (Table 8.2b). An examination of data table indicate that at this stage the

effect of seed rates in increasing the dry matter yield was more pronounced as it was increased from S_1 to S_2. The differences between S_2 and S_3 were not so marked.

During both the years, it was seen that $S_3F_3M_2$ resulted in highest dry matter production. It was interesting to note that during both the years at each seed rate a medium level of FYM (F_2) with M_2 was either more efficient or as efficient as F_3 with M_1 method of FYM application.

Table 8.2b. Effect of S x F x M interaction on dry matter production (g/m^2) at 14 WAS (1982-83 and 1983-84)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	320.4	334.1	339.6	342.3	347.4	360.5
S_2	360.7	357.2	350.4	359.1	372.2	338.7
S_3	358.2	363.9	362.2	360.5	380.9	381.1
SEm±			3.4			
CD5%			9.6			
			1983-84			
S_1	209.4	222.0	235.9	223.3	234.7	275.8
S_2	241.7	239.0	243.1	242.9	261.2	278.3
S_3	246.5	270.1	284.7	252.7	286.2	292.1
SEm±			10.2			
CD5%			28.3			

The interaction effects between S x F, at 6 WAS in 1983-84 and S x F at 18 WAS in 1982-83 (Appendix XX), S x M at 6 WAS in 1983-84, S x M at 18 WAS in 1983-84, S x M at harvest in 1984-85 (Appendix XXII), F x M at 6 WAS in 1982-83

(Appendix XXIII). S x F x M at 18 WAS in 1982-83 (Appendix XXV) were found to be significant only during one year and have, therefore been given in the Appendix section.

4.1.6. Per cent dry matter accumulation

The data on the progressive per cent dry matter accumulation at different stages have been given in Table 9. On those stages where the variation in the data was below 30 per cent, square root transformation was followed and where the variation ranged between 30 and 70 per cent, angular transformation was followed. The original values have been given in parenthesis in Table 9. The analyses of variance have been given in Appendix VI.

The treatment effect data (main effects) presented in Table 9 reveal that there was a steep rise in the per cent dry matter accumulation after 10 WAS to harvest stage during all the 3 years. The higher seed rate (S_3) resulted in higher per cent dry matter accumulation which differed significantly from the lower seed rate (S_1) in all the 3 years. However, in 1982-83 at 10, 14 and 18 WAS, S_3 and S_2 were at par with each other. During rest of the two years also a similar trend was observed at 10 WAS and harvest but 14 WAS significant differences were not found at all.

FYM rates also influenced the per cent dry matter accumulation at all the stages of crop growth in all the 3 years except in 1983-84 and 1984-85 at 6 WAS where no significant effect was noticed. During all the 3 years of experimentation, at all the growth stages, the higher FYM level of 15 t/ha resulted in significantly higher dry matter production as compared to 5 t/ha level of FYM. With the exception of that at 14 and 18 WAS and at harvest in 1984-85 and at 18 WAS in 1983-84, 15 t/ha also resulted in significantly higher dry matter production as compared to 10 t/ha.

Table 9. Treatment effects on per cent dry matter accumulation at various stages of crop growth

Treatments	Weeks after sowing (WAS)														
	6			10			14			18			Harvest		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)															
100	4.53 (20.1)	4.38 (18.8)	4.60 (20.7)	5.01 (24.6)	4.82 (20.8)	5.10 (25.6)	37.4 (36.5)	36.5 (37.5)	38.8 (39.3)	43.3 (47.1)	42.4 (45.5)	42.3 (48.8)	57.0 (70.3)	54.9 (65.0)	57.4 (71.0)
125	4.57 (20.4)	4.46 (19.4)	4.68 (21.5)	5.06 (25.2)	4.86 (23.1)	5.16 (26.1)	37.6 (37.3)	36.7 (35.8)	39.1 (39.8)	43.6 (47.6)	42.6 (45.9)	44.4 (49.2)	57.1 (70.6)	55.7 (68.3)	58.2 (72.2)
150	4.62 (20.9)	4.48 (19.6)	4.75 (22.1)	5.06 (25.2)	4.89 (23.5)	5.15 (26.2)	37.6 (37.3)	36.6 (35.6)	38.6 (39.8)	43.8 (48.0)	42.5 (45.7)	44.6 (49.3)	57.5 (71.2)	55.9 (68.6)	58.5 (72.7)
SEm±	0.01	0.02	0.03	0.01	0.008	0.01	0.06	0.1	0.2	0.1	0.03	0.05	0.1	0.09	0.05
C.D.5%	0.04	0.06	0.08	0.03	0.02	0.03	0.1	NS	NS	0.3	0.1	0.1	0.3	0.2	0.1
B. FYM rates (t/ha)															
5	4.55 (20.2)	4.44 (19.2)	4.67 (21.4)	5.00 (24.6)	4.83 (22.9)	5.11 (25.6)	37.3 (36.4)	36.4 (35.3)	38.2 (39.1)	43.2 (47.0)	42.3 (45.4)	44.3 (48.9)	56.8 (70.1)	55.2 (65.5)	57.5 (71.3)
10	4.56 (20.3)	4.44 (19.2)	4.68 (21.4)	5.04 (25.0)	4.86 (23.2)	5.15 (26.1)	37.6 (37.3)	36.5 (35.5)	39.1 (39.8)	43.6 (47.6)	42.6 (45.9)	44.5 (49.2)	57.2 (70.7)	55.6 (68.2)	58.1 (72.1)
15	4.62 (20.9)	4.45 (19.3)	4.68 (21.4)	5.08 (25.4)	4.88 (23.3)	5.16 (26.2)	37.6 (37.4)	36.9 (36.0)	39.2 (40.0)	43.8 (48.0)	42.6 (45.8)	44.6 (49.2)	57.6 (71.4)	55.7 (68.3)	58.4 (72.6)
SEm±	0.01	0.01	0.03	0.01	0.008	0.01	0.06	0.1	0.2	0.1	0.03	0.05	0.1	0.09	0.05
CDD.5%	0.04	NS	NS	0.03	0.02	0.03	0.1	0.3	0.7	0.3	0.1	0.1	0.3	0.2	0.1
C. Application methods															
Incorporation	4.52 (20.0)	4.38 (18.7)	4.67 (21.4)	5.01 (24.7)	4.83 (22.9)	5.12 (25.8)	37.3 (37.8)	36.4 (35.3)	38.8 (39.3)	43.1 (46.8)	42.3 (45.3)	44.3 (48.8)	56.8 (70.1)	55.3 (67.7)	57.7 (71.6)
Surface applied	4.63 (20.9)	4.50 (19.8)	4.68 (21.5)	5.07 (25.3)	4.88 (23.3)	5.16 (26.2)	37.7 (37.2)	36.8 (36.0)	38.9 (39.9)	44.0 (48.3)	42.7 (46.1)	44.7 (49.4)	57.6 (71.3)	55.7 (68.3)	58.3 (72.4)
SEm±	0.01	0.01	0.02	0.01	0.007	0.01	0.05	0.09	0.2	0.09	0.03	0.04	0.9	0.09	0.04
C.D.5%	0.03	0.04	NS	0.03	0.02	0.02	0.1	0.2	NS	0.26	0.1	0.1	0.2	0.2	0.1
C.V.(%)	1.49	2.20	3.15	1.24	0.89	1.11	0.91	1.62	3.25	1.28	0.44	0.58	0.97	0.84	0.48

( ) Figures in parenthesis are the original values.

As regards methods of FYM application (M_1 and M_2), the per cent dry matter accumulation was influenced significantly almost at all the stages in all the 3 years. It was seen that the surface method FYM application (M_2) significantly accumulated higher per cent dry matter and differed significantly from the incroporation method (M_1). Only at 6 and 14 WAS in 1984-85 the difference was not significant.

During all the 3 years at 18 WAS the S x M interaction influenced the per cent dry matter accumulation significantly, the interaction effect data presented in Table 9.1a reveal that at M_1 in 1982-83 and 1983-84 the increase in seed rates did not result in a significant increase in per cent dry matter yield. In 1984-85, the increase was significant but only upto S_2 level. At M_2 in 1982-83 each increase in seed rate resulted in a significant increase in per dry matter yield but the differences were not significant in 1984-85. In 1983-84 the increase was significant only upto S_2 level.

Table 9.1a. Effect of S x M interaction on per cent dry matter(transformed) at 18 WAS (1982-83, 1983-84 and 1984-85)

Seed rates	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
S_1	43.1 (46.8)	43.5 (47.4)	42.2 (45.2)	42.5 (45.8)	44.0 (48.3)	44.6 (49.3)
S_2	43.2 (46.9)	43.9 (48.3)	42.3 (45.3)	42.9 (40.5)	44.5 (49.2)	44.6 (49.4)
S_3	43.1 (46.8)	44.5 (50.0)	42.3 (45.5)	42.8 (46.0)	44.4 (49.0)	44.8 (49.7)
SEm±	0.1		0.04		0.7	
CD5%	0.4		0.1		0.2	

Table 10. Treatment effects on days to 50% , 100% heading and maturity

Treatment	Days to 50 per cent heading			Days to 100 per cent heading			Days to maturity		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)									
100	103.0	97.0	92.8	114.7	108.6	103.3	132.4	124.2	123.1
125	105.6	98.1	93.7	115.4	110.0	104.6	133.9	125.1	124.1
150	107.2	99.6	94.0	116.8	110.3	105.9	135.2	125.4	124.9
SEm±	0.4	0.5	0.3	0.4	0.5	0.4	0.3	0.2	0.4
C.D.5%	1.1	1.6	NS	1.3	NS	1.1	1.0	0.8	1.2
B. FYM rates (t/ha)									
5	106.1	99.9	95.2	116.2	110.9	105.5	136.1	126.6	125.3
10	105.0	98.7	93.6	115.7	109.7	104.7	133.5	125.1	124.5
15	104.8	96.1	91.7	115.0	108.3	103.7	131.9	123.0	122.5
SEm±	0.4	0.5	0.3	0.4	0.5	0.4	0.3	0.2	0.4
C.D.5%	NS	1.6	1.1	NS	1.4	1.1	1.0	0.8	1.2
C. Application methods									
Incorporation	104.7	98.1	93.0	115.3	108.8	103.5	132.2	124.5	122.8
Surface applied	105.8	98.3	94.0	116.0	110.5	105.8	135.4	125.3	125.3
SEm±	0.3	0.4	0.3	0.3	0.4	0.3	0.2	0.2	0.3
C.D.5%	0.9	NS	0.9	NS	1.1	0.9	0.8	0.6	1.0
C.V.(%)	1.8	2.8	2.0	1.9	2.2	1.9	1.3	1.1	1.7

When the methods of FYM application were compared at different seed rates, it was seen that with the exception of that at S_2 in 1984-85, the surface method of FYM application (M_2) always resulted in significantly higher per cent dry matter accumulation as compared to incorporation method (M_1).

Among the first order single year interactions S x F at 10, 18 WAS and at harvest in 1982-83 and 1984-85, S x M at 14 WAS in 1982-83 and at harvest in 1984-85, F x M interaction at 6 WAS in 1982-83 at 18 WAS in 1983-84 and at harvest in 1984-85. Since these interactions were significant only for one year, therefore have been presented in Appendix XX, XXII and XXIII, respectively.

The 2nd order of interactions S x F x M at 10 WAS in 1982-83 and at harvest in 1984-85 also presented in Appendix XXV, were found to have a significant effect on dry matter accumulation but only for one year and have not, therefore, been discussed.

4.2. Development stages of wheat

4.2.1. Heading

Data pertaining to the days taken to 50 and 100 per cent ear emergence and to maturity of wheat have been given in Table 10. Their analyses of variance have been given in Appendix VII.

4.2.2. 50 per cent heading: A perusal of data presented in Table 10 reveal that as the seed rate was increased the number of days taken to 50 percent ear emergence also increased. In 1982-83, each increase in seed rate resulted in corresponding significant increase in the days taken to complete 50 per cent ear emergence but in 1983-84 the significant difference was found only between 150 and 100 kg seed rate/ha. In 1984-85 the seed rate did not differ significantly.

FYM levels, i.e. 5, 10 and 15 t/ha did not influence the number of days taken to 50 per cent ear emergence significantly in 1982-83 and 1984-85. In

1983-84 the higher level of FYM (15 t/ha) rather helped in producing early ear emergence and 50 per cent ear emergence was completed significantly earlier as compared to 5 and 10 t/ha FYM rates. The latter two treatments were at par with each other. During 1984-85 each increase in FYM rates resulted in significantly decreased days taken to 50 per cent ear emergence. The incroproation of FYM in the soil (M_1) also helped in inducing early emergence and in 1982-83 and 1984-85 the differences were even significant.

First order interaction F x M and 2nd order interaction S x F x M in 1983-84 was found to significantly affect the 50 per cent ear emergence. The interaction effect data have been presented in Appendix XXIII and XXV, respectively.

4.2.3. <u>100 per cent heading</u>: The data on the number of days taken to complete heading also presented in Table 10 reveal that the increase in seed rates from 100 to 150 kg/ha delayed the completion of ear emergence from 1 to 2 days. In 1983-84, the difference was not significant but in 1984-85 each increase in seed rates resulted in significant delayed completion of ear emergence. In 1982-83, however, only S_3 resulted in significant delay.

Like 50 per cent ear emergence, the complete ear emergence was also hastened when the FYM rates were increased. The significant difference, however was found only between 15 and 5 t/ha rates in 1983-84 and 1984-85. In 1982-83 the FYM rates, however, did not differ.

In 1982-83, the methods of application of FYM did not influence the days taken for 100 per cent heading. However, during rest of the two years, surface application of FYM (M_2) differed significantly from M_1.

In 1983-84, S x F, S x M, F x M and S x F x M interactions influenced the days taken to 100 per cent heading significantly and are presented in Appendix XX, XXII, XXIII and XXV, respectively. Since these interactions were found to be significant only during one year therefore a discussion on these was not found to be meaningful.

4.2.14. Maturity: The data on the days taken to maturity embodied in Table 10 show that the seed rates influenced the days taken to maturity of wheat crop. In 1982-83, seed rate 100 kg/ha took 2-3 days lesser than 125 kg/ha and 3 days less than 150 kg/ha to complete the maturity and each seed rate differed significantly from one another. In 1983-84 150 kg and 125 kg/ha seed rates while remaining at par with each other took significantly more days compared to 100 kg/ha to mature. In 1984-85, 100 kg/ha which took least number of days to maturity was found to be at par with 125 kg/ha but differed significantly from 150 kg/ha. 125 and 150 kg/ha seed rates were also at par with each other.

During all the 3 years of experimentation, FYM rates significantly influenced the days taken to maturity. An increase in FYM rates resulted in lesser number of days to maturity. During first two years of experimentation each increase in FYM rates resulted in a significant decrease in the number of days to maturity. Whereas, in 1984-85, 5 and 10 t/ha FYM rates while remaining at par with each other differed significantly from 15 t/ha rate of FYM application.

During all the 3 crop seasons, surface application of FYM (M_2) took more number of days for the maturity of wheat as compared to incorporated FYM in the soil (M_1) and differed significantly.

S x F interaction influenced significantly the days taken to maturity in 1982-83 and 1983-84. The interaction effect data presented in Table 10a show that in 1982-83 at F_3, S_1 recorded the lowest number of days taken to maturity and each increase in seed rate resulted in a significant increase in the days taken to maturity. But at the same level of FYM(i.e. F_3) in 1983-84, S_2 resulted in the lesser number of days taken to maturity, which remained at par with S_1 and differed significantly from S_3. At F_2 none of the seed rates differed significantly during both the years. At fixed seed rate, with the increase in the levels of FYM at S_1 in 1982-83 and at S_2 in 1983-84, F_3 resulted in the minimum days taken to maturity and each FYM rate differed significantly. At S_1 also, in 1983-84, F_3 recorded lesser number of days to maturity which differed significantly from F_1 and F_2. The latter two FYM rates remained at par with each other. At higher seed rates S_3 in 1983-84, the increased level of FYM did not differ significantly but in 1982-83 contrary to that at S_1 and S_2 at S_3, F_3 took more days to maturity and each rate of FYM differed significantly.

Table 10.1a. Effect of S x F interaction on days taken to maturity (1982-83 and 1983-84)

Seed rates	1982-83			1983-84		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	139.3	131.9	124.8	126.1	124.7	122.0
S_2	131.8	139.5	130.4	128.2	125.4	121.6
S_3	136.6	128.7	141.1	125.6	125.4	125.3
SEm±		0.7			0.5	
CD5%		2.0			1.6	

In the year 1982-83 as well as in 1983-84, S x M interaction significantly influenced the days taken to maturity. The interaction effect data presented in Table 10.1b show that in 1982-83 a medium seed rate of 125 kg/ha (S_2) in which FYM was incorporated in soil (M_1) helped in early maturity and the treatment combinations S_2M_1 recorded significantly lowest number of days as compared to other treatment combinations. In 1983-84, S_1M_1 treatment combination recorded the lowest number of days to maturity.

Table 10.1b. Effect of S x M interaction on days taken to maturity (1982-83 and 1983-84

Seed rates	1982-83		1983-84	
	M_1	M_2	M_1	M_2
S_1	132.0	132.7	120.5	128.0
S_2	129.0	138.8	127.4	122.8
S_3	135.5	134.8	125.7	125.1
SEm$\pm$	0.5		0.4	
CD5%	1.4		1.6	

In 1982-83 and 1983-84, F x M interaction also influenced the days taken to maturity. The interaction effect data presented in Table 10.1c show that during both the years, with each method, as the rate of FYM was increased the number of days taken to maturity decreased. Only in 1982-83 the trend was slightly reversed at M_1 as F_1 was increased to F_2. Also, the incorporation of FYM into the soil (M_1) resulted in lesser number of days to maturity. Only in 1983-84 at F_1 the trend was slightly reversed.

Table 10.1c. Effect of F x M interaction on number of days taken to maturity 1982-83 and 1983-84

FYM levels	1982-83		1983-84	
	M_1	M_2	M_1	M_2
F_1	131.6	140.5	128.0	125.2
F_2	133.5	133.5	124.0	126.2
F_3	131.5	132.3	121.5	124.5
SEm$\pm$	0.5		0.4	
CD5%	1.4		1.6	

The second order of interaction (S x F x M) significantly influenced the days taken to maturity in 1982-83 and 1983-84. The data presented in Table 10.2a show that in 1982-83 the treatment combination $S_2F_1M_1$ took the lowest number of days to maturity and it differed significantly from rest of the treatment combinations. It was followed by $S_1F_3M_1$ but it was at par with $S_1F_3M_2$. In 1983-84, however, $S_1F_3M_1$ took lowest number of days to maturity and including $S_1F_3M_2$ it differed significantly from all other SFM treatment combinations.

Table 10.2a. Effect of S x F x M interaction on days taken to maturity 1982-83 and 1983-84

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	139.7	132.0	124.5	140.0	132.7	125.5
S_2	119.0	138.5	129.7	145.0	140.7	130.7
S_3	136.2	130.0	140.5	136.7	127.0	140.7
SEm±			1.1			
CD5%			3.0			
			1983-84			
S_1	124.0	120.7	116.7	128.2	128.5	127.5
S_2	128.5	127.5	126.2	128.0	123.2	117.2
S_3	132.0	123.7	121.7	119.5	127.0	129.0
SEm±			0.8			
CD5%			2.4			

4.3. Yield contributing characters

The effect of different treatments on yield contributing characters such as number of effective tillers m^{-1} row length, spike length, spikelets/spike, grains/spike and 1000-grain weight has been presented in Table 11. The corresponding analyses of variance have been given in Appendix VIII.

4.3.1. Number of effective tillers

A perusal of data presented in Table 11 show that the seed rates increased the number of effective tillers m^{-1} row length in all the 3 years of the experimentation. However, 125 and 150 kg/ha seed rates remained at par with each other in 1982-83 and 1984-85. Both the seed rates differed significantly from 100 kg seed rate/ha. During the year 1983-84, however, each seed rate differed significantly from one another.

An increase in FYM rate also increased the effective number of tillers during all the 3 years. In 1982-83, however, the lower FYM rates (5 and 10 t/ha) while remaining at par with each other differed significantly from 15 t/ha. On the other hand in 1983-84 the higher FYM rates (10 and 15 t/ha) remained at par and differed significantly from 5 t/ha rate of FYM application. In 1984-85 the tiller number did not vary significantly due to FYM rates.

The surface application of FYM (M_2) recorded higher number of effective tillers and differed significantly with the FYM incorporated into the soil(M_1) during all the 3 years of experimentation.

The analyses of variance revealed that S x F interaction significantly affected the number of effective tillers m^{-1} row length in all the 3 years. The interaction effect data presented in Table 11.1a reveal that an increase in seed rate resulted in corresponding increase in number of effective tillers at all the levels of FYM. In some of the cases, however, the significant increase

Table 11. Treatment effects on yield contributing characters in wheat

Treatments	No. of effective tillers m^{-1}			Spike length (cm)				Spikelets/spike				Grains/spike				1000-grain weight (g)			
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	Pooled	1982-83	1983-84	1984-85	Pooled	1982-83	1983-84	1984-85	Pooled	1982-83	1983-84	1984-85	Pooled
A. Seed rates (kg/ha)																			
100	76.4	50.5	60.0	8.8	8.2	9.3	8.8	14.2	13.1	14.0	13.8	33.3	25.8	30.7	29.9	40.0	38.2	46.6	41.6
125	80.7	53.9	64.2	8.2	8.2	9.3	8.6	13.6	12.7	13.6	13.3	31.1	25.4	29.6	28.7	39.4	38.1	46.2	41.2
150	84.7	56.4	65.7	8.3	7.8	9.2	8.4	13.4	12.5	13.7	13.2	30.8	24.1	29.3	28.1	39.1	37.7	45.7	40.8
SEm±	1.4	0.6	1.1	0.08	0.1	0.1	0.06	0.2	0.2	0.1	0.1	0.3	0.3	0.2	0.2	0.2	0.2	0.5	0.2
C.D.5%	4.1	1.8	3.2	0.2	NS	NS	0.2	0.5	NS	NS	0.3	1.0	1.0	0.7	0.5	0.6	NS	NS	0.6
B. FYM rates (t/ha)																			
5	77.7	47.4	62.6	8.4	7.8	9.1	8.4	13.5	12.4	13.5	13.2	31.1	24.3	28.7	28.0	38.9	37.5	45.2	40.5
10	80.9	56.0	63.2	8.4	8.2	9.2	8.6	13.8	12.8	13.8	13.5	31.5	25.3	29.4	28.7	39.3	38.1	46.1	41.2
15	83.2	57.4	64.2	8.5	8.2	9.5	8.7	13.9	13.1	14.0	13.7	32.6	25.8	31.5	29.9	40.3	38.5	47.3	42.0
SEm±	1.4	0.6	1.1	0.08	0.1	0.1	0.06	0.1	0.2	0.1	0.1	0.3	0.3	0.2	0.2	0.2	0.2	0.5	0.2
C.D.5%	4.1	1.8	NS	NS	NS	NS	0.2	NS	NS	NS	0.3	1.0	1.0	0.7	0.5	0.6	0.7	1.5	0.6
C. Application methods																			
Incorporation	77.5	52.1	61.9	8.3	7.9	9.1	8.4	13.1	12.5	13.7	13.1	31.1	24.1	29.0	28.1	38.9	37.5	46.1	40.8
Surface applied	83.8	55.0	64.8	8.6	8.2	9.5	8.8	14.4	13.0	13.9	13.7	32.3	26.1	30.7	29.7	40.1	38.6	46.3	41.6
SEm±	1.1	0.5	0.9	0.06	0.1	0.2	0.04	0.1	0.1	0.1	0.08	0.3	0.3	0.2	0.1	0.2	0.2	0.4	0.2
C.D.5%	3.3	1.4	2.6	0.2	NS	NS	0.1	0.4	NS	NS	0.2	0.8	0.9	0.5	0.4	0.5	0.6	NS	0.5
C.V.(%)	8.8	5.9	8.8	4.3	9.1	9.6	3.8	6.3	8.7	7.1	4.0	5.6	7.1	4.0	3.0	2.7	3.3	5.7	2.5

was found only upto S_2 whereas in some of the cases to obtain a significant increase the seed rate had to be increased upto S_3 level. The effect of FYM levels at different seed rates during different years was not consistent. In 1982-83 the increase in FYM rate brought an increase in tiller number only upto F_2 level and that too at S_2 only. In 1983-84 at S_1 and S_2 the significant increase was noticed only upto F_2. Whereas at S_3, each increase in FYM resulted in a significant increase in tiller number. In 1984-85, however, this consistency was not maintained.

Table 11.1a. Effect of S x F interaction on effective tillers m^{-1} row length (1982-83, 1983-84 and 1984-85).

Seed rates	1982-83			1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	73.8	75.9	77.1	45.0	55.3	50.8	63.4	58.6	56.6
S_2	71.8	82.2	86.5	48.3	57.3	55.6	60.0	63.2	69.9
S_3	85.1	85.0	88.1	48.7	56.5	64.4	65.1	67.7	65.2
SEm$\pm$		2.9			1.2			2.2	
CD5%		8.3			3.6			6.4	

F x M interaction effect which also influenced the effective number of tillers significantly during all the 3 years have been presented in Table 11.1b. The data table shows that with the exception of that at M_1 in 1982-83 and at M_2 in 1984-85 an increase in FYM level resulted in corresponding increase in tiller number. The increase, however, was more consistent upto F_2 level. Also the surface method appeared to be more conducive for inducing higher tiller number. Only at F_1 in 1982-83 and at F_2 in 1984-85, the trend was reversed.

Table 11.1b. Effect of F x M interaction on number of effective tillers m^{-1} row length (1982-83, 1983-84 and 1984-85)

FYM levels	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
F_1	80.4	75.0	43.2	51.5	56.5	68.6
F_2	77.7	84.1	55.9	56.2	65.7	60.7
F_3	74.3	92.1	57.4	57.4	63.4	65.0
SEm±	2.0		0.9		1.6	
CD5%	5.9		2.6		4.6	

Second order interaction (S x F x M) which influenced the effective number of tillers significantly only in 1983-84 has been presented in Appendix XXVI.

4.3.2. Spike length

A perusal of the data on the spike length presented in Table 11 reveal that the seed rates affected the spike length significantly only in 1982-83. But the treatment effects pooled over 3 years also showed that the seed rates had a significant effect on spike length. Both in 1982-83 as well as in pooled analysis it was seen that 100 kg/ha seed rate resulted in spikes with greater length. It was seen in the pooled analysis that each increase in seed rate resulted in significant decrease in spike length.

The FYM rates did not influence the spike length significantly during the 3 years of experimentation but it was seen in the pooled analysis that contrary to seed rates, the increase in FYM rates resulted in an increase in spike length and the difference between 5 and 15 t/ha was found to be significant.

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5 and 10 t/ha and 10 and 15 t/ha FYM level, however, remained at par with each other. In respect of the methods of application of FYM it was seen that the surface method of application resulted in spikes with greater length. Only in 1983-84 the difference was not found to be significant.

None of the interactions influenced the spike length significantly.

4.3.3. Number of spikelets/spike

The effect of different treatments on the number of spikelets/spike also presented in Table 11 shows that in 1983-84 and 1984-85 the effect of seed rates was not significant but in 1982-83 as well as in the pooled analysis it was seen that a seed rate of 100 kg/ha recorded the maximum spikelets/spike and differed significantly from latter two seed rates. The latter two seed rates (125 and 150 kg/ha) remained at par with each other.

FYM rates did not influence the spikelets/spike significantly during all the 3 years but when the data were pooled together the effect turned out to be significant and it was seen that the number of spikelets/spike increased with FYM rates. The differences between 5 and 10 t/ha was not significant but both of them recorded lower number of spikelets/spike when compared with 15 t/ha.

The surface method of FYM application resulted in higher number of spikelets/spike but the difference was not significant in 1983-84 and 1984-85.

In the pooled analysis it was seen that S x F interaction influenced the number of spikelets/spike significantly. The interaction effect data presented in Table 11.1c show that at each rate of FYM a lower seed rate resulted in higher number of spikelets/spike and it was seen that at F_1, the two higher seed rates (S_2 and S_3) while remaining at par with each other, recorded significantly lower number of spikelets/spike, as compared to S_1. At F_2, S_1

recorded significantly higher number of spikelets/spike when compared with S_2 but was at par with S_3. At F_3, S_1 and S_2 were at par with each other but both of them recorded significantly higher number of spikelets/spike as compared to S_3.

Table 11.1c. Effect of S x F interaction on number of spikelets/spike(Pooled data)

Seed rates	F_1	F_2	F_3
S_1	13.6	13.7	14.1
S_2	13.1	13.1	13.8
S_3	12.9	13.7	13.0
SEm±		0.3	
CD5%		1.0	

Similarly, at each seed rate an increase in FYM rates also recorded an increase in number of spikelets/spike. The difference, however, was not significant at S_1 but at S_2, F_1 and F_2 while remaining at par with each other, resulted in significantly lower number of spikelets/spike when compared with F_3. At S_3, the significant difference was found only between F_1 and F_2.

4.3.4. Number of grains/spike

The data on the number of grains/spike for 3 years and pooled analysis have been given in Table 11. The analyses of variance have also been embodied in Appendix VIII.

An examination of the data on the number of grains/spike presented in Table 11 shows that the grains/spike decreased by increasing the seed rates. During all the 3 years, it was seen that the significant decrease resulted only upto 125 kg seed rate/ha but in the pooled analysis it was seen that the difference between 125 and 150 kg seed rates was also significant. Contrary to this an increase in FYM rates resulted in corresponding increase in grains/spike. It was seen in the pooled analysis that each level of FYM differed significantly from one another.

The methods of application of FYM significantly influenced this attribute in all the 3 years as well as when pooled. Surface application of FYM (M_2) resulted in higher number of grains/spike which differed significantly from the incorporation of FYM into the soil (M_1).

S x F interaction effect was found to be significant in the pooled analysis (Table 11.1d). In general, it was seen that at each FYM level an increase in seed rate resulted in a decrease in grains/spike. At F_1, S_1 was followed by S_3 but at F_2, S_1 was followed by S_2 and S_3 and each seed rate differed significantly from one another. At F_3, S_1 and S_2 remained on par with each other but both of them recorded significantly higher number of grains/spike compared to S_3.

Table 11.1d. Effect of S x F interaction on number of grains/spike (Pooled)

Seed rates	F_1	F_2	F_3
S_1	29.2	30.2	30.5
S_2	27.0	28.6	30.4
S_3	28.1	27.0	29.1
SEm±		0.3	
CD5%		1.0	

The effect of FYM levels was more consistent at two lower seed rates where it was seen that an increase in FYM application rates resulted in an increase in grains/spike. At S_1, F_2 and F_3 while remaining at par with each other resulted in significantly higher number of grains/spike as compared to F_1. At S_1 each increase in FYM rates resulted in a significant increase in grains/spike.

The S x M interaction effect in the pooled analysis was also found to influence the grains/spike significantly. The data presented in Table 11.1d show that with both the methods a lower seed rate resulted in higher number of grains/spike.

Table 11.1e. Effect of S x M interaction on number of grains/spike (Pooled)

Seed rates	M_1	M_2
S_1	28.4	31.4
S_2	28.4	29.1
S_3	25.5	28.7
SEm±	0.2	
CD5%	0.7	

With M_1, S_1 and S_2 while remaining at par with each other differed significantly from S_3. With M_2, S_1 differed significantly even from S_2. The two higher seed rates (S_2 and S_3) however, remained at par with each other. It was interesting to note that at each seed rate, the surface method of FYM application (M_2) resulted in significantly higher number of grains/spike.

Among the second order of interactions, S x F x M interaction influenced the number of grains/spike significantly in the pooled analysis. It may be seen from the data (Table 11.2a) that $S_1F_3M_2$ resulted in the highest grains/spike which differed significantly from rest of the SFM treatment combinations.

Table 11.2a. Effect of S x F x M interaction on number of grains/spike (Pooled)

Seed rates	M_1 F_1	F_2	F_3	M_2 F_1	F_2	F_3
S_1	28.2	29.6	27.5	30.0	31.0	33.2
S_2	26.7	28.9	29.5	27.3	28.7	31.4
S_3	27.1	25.2	30.1	28.9	29.1	28.0
SEm±			0.5			
CD5%			1.4			

Only those interactions which were found to influence the number of grains/spike significantly in the pooled analysis have been discussed. The individual interactions such as S x F interaction during all the three years, S x M in 1983-84 and in 1984-85, F x M in 1983-84 and S x F x M in 1983-84 and in 1984-85 have been given in the appendix section (Appendix XX, XXII, XXIII, and XXVI, respectively).

4.3.5. 1000-grain weight

The effect of different treatments on 1000-grain weight also presented in Table 11 shows that an increase in seed rates resulted in a decrease in 1000-grain weight. The effect, however, was significant only in 1982-83 and when the data were pooled together. It was seen in the pooled analysis that 100 kg seed rate resulted in highest 1000-grain weight but it differed significantly only from 150 kg seed rate/ha. The two higher seed rates were also at par with each other.

Contrary to this, an increase in FYM rates resulted in corresponding increase in 1000-grain weight. During all the three years as well as in the pooled analysis, 5 t/ha FYM resulted in lowest 1000-grain weight. During individual years the differences due to each increase in GFYM level was not significant but in the pooled analysis it was seen that each increase in FYM level resulted in a significant increase in 1000-grain weight.

During all the three years surface method of FYM application resulted in higher 1000-grain weight. The difference, however was not significant in 1984-85 but during rest of the two years and in the pooled analysis surface application resulted in significantly higher 1000-grain weight.

In the pooled analyses S x F interaction affected the 1000-grain weight significantly. The interaction effect data presented in Table 11.1f show that at F_1 and F_2, increase in seed rates did not influence the 1000-grain weight significantly. However, at F_3, S_3 while remaining at par with S_1 recorded significantly lower 1000-grain weight as compared to S_2.

Table 11.1f. Effect of S x F interaction on 1000-grain weight (Pooled)

Seed rates	F_1	F_2	F_3
S_1	41.0	41.6	42.1
S_2	40.6	40.5	42.7
S_3	39.8	41.7	41.1
SEm±		0.4	
CD5%		1.2	

The FYM rates did not differ at S_1 but at S_2, F_3 recorded significantly higher 1000-grain weight. At S_3, F_2 and F_3 while remaining at par with each other recorded significantly higher 1000-grain weight in comparison to F_1.

In the pooled analysis F x M interaction was also found to influence the 1000-grain weight significantly. The data presented in Table 11.1g reveal that at M_1, F_3 recorded the highest 1000-grain weight which differed significantly from F_1 and F_2. The latter two FYM rates were at par with each other. At M_2, F_2 resulted in maximum 1000-grain weight which remained at par with F_3 but differed significantly from F_1.

Table 11.1g. Effect of F x M interaction on 1000-grain weight (g) (Pooled)

FYM levels	M_1	M_2
F_1	40.1	40.9
F_2	40.3	42.0
F_3	42.1	41.9
SEm±	0.2	
CD5%	0.8	

The surface method of FYM application (M_2) however, showed its superiority over incorporation method (M_1) only at F_2.

The second order of interaction S x F x M when pooled over three crop seasons significantly affected the 1000-grain weight (Table 11.2b). The data table reveal that at S_2, F_3M_1 resulted in highest 1000-grain weight which was at par with $S_1F_3M_2$ and $S_3F_2M_2$ and differed significantly from rest of the treatment combinations. The lowest 1000-grain weight was recorded at $S_1F_2M_1$.

Table 11.2b. Effect of S x F x M interaction on 1000-grain weight (Pooled)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	40.6	38.5	41.6	41.5	42.4	42.7
S_2	39.6	39.6	44.2	41.7	41.2	41.3
S_3	40.0	40.6	40.5	39.6	42.5	41.8
SEm±			0.6			
CD5%			1.8			

Like grains/spike, in respect of 1000-grain weight also only those interactions have been discussed which came out to be significant in the pooled analysis. Other interactions, which were found to be significant during individual years viz., S x F, F x M, S x F x M in 1982-83 and 1984-85 have been presented in the appendix section only(Appendix XX, XXIII and XXVI, respectively).

4.3.6. Yield

The effect of different treatments on grain yield, straw yield and harvest index has been presented in Table 12. The treatment effects on grain and straw yield have also been depicted diagrammatically in Fig.6. The analyses of variance have been given in Appendix IX.

(a) Grain yield: An examination of data presented in Table 12 reveals that during all the 3 years, 100 kg seed rate resulted in lowest grain yield. In 1982-83, it was significantly lower than 125 and 150 kg seed rates. The latter two seed rates in turn were at par with each other. In 1983-84 and 1984-85 on the other hand 100 and 125 kg seed rates remained at par with each other but both resulted in significantly lower grain yield when compared with 150 kg seed rate per hectare.

In the pooled analysis it was seen that each increase in seed rate resulted in a significant increase in grain yield. Data in table as well as Fig.6 reveal that the yield levels were quite low in 1983-84.

In case of FYM rates it was seen that in 1982-83 and 1983-84 a significant increase in grain yield was observed when the rate of FYM was increased from 5 to 10 t/ha. Further increase to 15 t/ha did not result in a significant increase. In 1984-85 as well as in the pooled analysis, however, it was seen that each increase in FYM application rate resulted in a significant increase in grain yield.

Table 12. Treatment effects on grain and straw yield and harvest index

Treatments	Grain yield (kg/ha) 1982-83	1983-84	1984-85	Pooled	Straw yield (kg/ha) 1982-83	1983-84	1984-85	Pooled	Harvest Index 1982-83	1983-84	1984-85	Pooled
A. Seed rates (kg/ha)												
100	1899	1101	1356	1438	4294	1904	2688	2962	0.30	0.36	0.32	0.33
125	2232	1259	1467	1652	5224	2317	3073	3538	0.29	0.35	0.32	0.32
150	2341	1305	2218	1955	5716	2684	4746	4415	0.28	0.31	0.30	0.30
SEm±	75	43	60	31	137	86	125	65	0.006	0.01	0.01	0.01
C.D. 5%	215	125	171	91	391	244	356	184	0.01	0.03	0.02	0.02
B. FYM rates (t/ha)												
5	1874	1011	1428	1438	4493	1869	2816	3058	0.28	0.35	0.33	0.32
10	2228	1271	1679	1712	5297	2369	3635	3767	0.28	0.34	0.31	0.31
15	2371	1383	1933	1896	5444	2667	4156	4089	0.29	0.33	0.31	0.31
S.Em±	75	43	60	31	137	86	125	65	0.006	0.01	0.01	0.01
C.D. 5%	215	125	171	91	391	244	356	184	0.01	NS	0.02	NS
C. Application methods												
Incorporation	2087	1162	1521	1590	4913	2192	3288	3464	0.29	0.34	0.31	0.31
Surface applied	2257	1281	1839	1774	5243	2411	3784	3812	0.29	0.34	0.32	0.32
S.Em±	61	36	48	26	112	70	101	53	0.005	0.01	0.009	0.005
C.D. 5%	NS	102	139	74	319	200	290	150	NS	NS	0.01	NS
C.V. (%)	17.2	17.7	17.6	9.3	13.3	18.3	17.3	8.7	7.3	15.6	11.4	6.1

In respect of methods of FYM application it was observed that the two methods did not influence the grain yield significantly in 1982-83. However, in 1983-84 and 1984-85 and in the pooled analysis it was observed that the surface application of FYM proved to be significantly superior over incorporation of FYM into the soil.

S x F interaction effect that influenced the grain yield significantly in 1982-83 and 1983-84 have been presented in Table 12a. A perusal of the data reveals that increase in seed rate and FYM rate increased the grain yield significantly in both the years. In 1982-83, at F_1 and F_2 and in 1983-84 at F_2 the grain yield increased upto seed rate S_2 which remained at par with S_3 and differed significantly from S_1.

Table 12a. Effect of S x F interaction on grain yield kg/ha (1982-83 and 1983-84)

Seed rates	1982-83			1983-84		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	1390	1744	2270	973	1029	1274
S_2	1935	2448	2402	1092	1456	1260
S_3	2089	2588	2551	937	1412	1562
SEm±		151			88	
CD5%		430			250	

In 1982-83, at F_3 and 1983-84 at F_1, seed rates did not differ significantly. However, in 1983-84 at F_3, S_3 recorded maximum yield which differed significantly from S_1 and S_2. The latter two seed rates remained at par with each other.

At fixed seed rate in 1982-83 at S_2 and S_3, and in 1983-84 at all the seed rates the grain yield increased by increasing the FYM rate upto F_2 which remained at par with F_3 and differed significantly from F_1. However, in 1982-83 at lower seed rate S_1, F_1 recorded the lowest grain yield which remained at par with F_2 and differed significantly from F_3.

None of the interactions in the pooled analysis was found to influence the grain yield significantly.

(b) Straw yield: The data on straw yield as influenced by different treatments also presented in Table 12 show that during all the 3 years as well as in the pooled analysis each increase in seed rates resulted in a significant increase in straw yield, the highest being obtained at 150 kg seed rate/ha. Table 12 as well as Fig.6 show that in 1983-84 the yield level was quite low.

Like seed rates, in case of FYM rates also it was seen that during all the 3 years as well as when the data were pooled each increase in FYM rate resulted in a significant increase in straw yield.

The surface method of application of FYM showed its superiority over the incorporation method and resulted in significantly higher straw yield during all the 3 years of experimentation as well as in the pooled analysis.

None of the interaction effects were found to influence the straw yield significantly.

(c) Harvest index: The data on the harvest index as influenced by different treatments have also been presented in Table 12.

A perusal of the data table shows that the harvest index decreased with the increase in seed rate. Where each increase in seed rate in 1982-83 resulted in a significant decrease in harvest index, during rest of the two years as well as in the pooled analysis it was seen that the lower seed rates (100 and 125 kg/ha) remained at par with each other but both of them registered significantly higher harvest index as compared to 150 kg seed rate/ha.

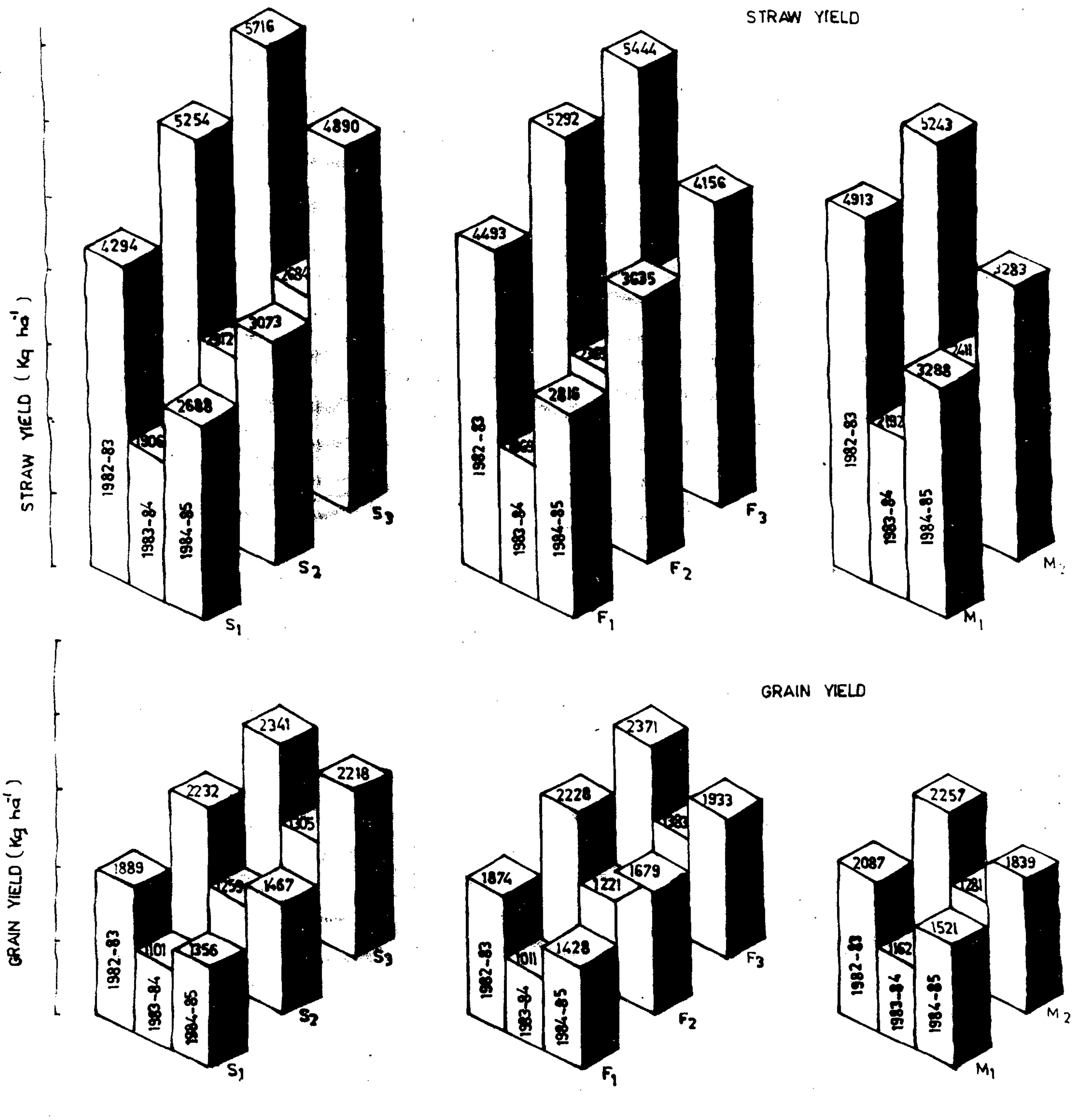


FIG. 6 EFFECT OF DIFFERENT TREATMENTS ON GRAIN AND STRAW YIELD (Kg ha^{-1})

In 1982-83 the harvest index increased with the increase in FYM rates but the trend was just reverse in 1983-84 and 1984-85. In the pooled analyses however, the effect was not significant. The methods of FYM application also, did not influence the harvest index significantly. Only in 1984-85 surface method showed its superiority over incorporation method. None of the interactions were significant in the pooled analyses, only in 1983-84 in case of seed rate x FYM rates (S x F) the interaction was found to influence the harvest index significantly. The data pretaining to the interaction have been given in Appendix XX.

4.4. Plant chemical studies

4.4.1. Nitrogen content(%) in plants

The data on the N content in wheat plant at 6, 10, 14, 18 WAS and in straw and grains at harvest as affected by main treatments of experimentation in 1982-83, 1983-84 and 1984-85 have been given in Table 13. The corresponding analyses of variance for the respective years have been given in Appendix X. The content of N at different stages upto 18 WAS in all the three crop seasons have also been presented graphically in Fig.7. The content in straw and grains at harvest has been shown in Fig.8.

An examination of Fig.7 reveals that in general the N content in plant was higher at 6 WAS and fell progressively as the crop advanced towards maturity.

A perusal of data presented in Table 13 indicates that with the exception of straw in 1982-83 and 1984-85, the seed rates significantly affected N content (%) in the plant during all the 3 years of the study. In 1982-83 at 6 and 18 WAS and in 1984-85 at 10 WAS, the N content in plants increased significantly with increase in seed rate upto 150 kg/ha but it was at par with 125 kg/ha and differed significantly with 100 kg/ha. In 1984-85 at 6 WAS and

Table 13. Treatment effects on N content (%) in plant at various stages of crop growth

Treatments	Weeks After Sowing (WAS)																	
	6			10			14			18			Straw			Grain		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)																		
100	2.34	2.32	2.47	1.29	1.49	1.31	0.59	0.70	0.84	0.57	0.60	0.72	0.52	0.57	0.52	1.49	1.56	1.60
125	2.40	2.37	2.59	1.32	1.53	1.38	0.60	0.73	0.92	0.67	0.64	0.78	0.53	0.54	0.52	1.55	1.57	1.73
150	2.42	2.61	2.69	1.40	1.60	1.40	0.64	0.78	1.45	0.65	0.71	1.20	0.54	0.58	0.54	1.62	1.65	1.78
SEm±	0.01	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.04	0.008	0.02	0.04	0.01	0.006	0.01	0.009	0.01	0.01
C.D.5%	0.02	0.07	0.09	0.03	0.05	0.02	0.02	0.04	0.012	0.02	0.05	0.11	NS	0.02	NS	0.02	0.03	0.03
B. FYM rates (t/ha)																		
5	2.34	2.32	2.48	1.33	1.43	1.33	0.59	0.70	0.91	0.57	0.58	0.74	0.50	0.53	0.50	1.47	1.55	1.67
10	2.39	2.39	2.54	1.34	1.58	1.36	0.52	0.75	1.03	0.61	0.61	0.86	0.54	0.56	0.52	1.57	1.58	1.69
15	2.41	2.60	2.73	1.34	1.61	1.39	0.63	0.76	1.27	0.71	0.76	1.09	0.56	0.60	0.56	1.63	1.65	1.75
SEm±	0.01	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.04	0.008	0.02	0.04	0.01	0.006	0.01	0.009	0.01	0.01
C.D.5%	0.02	0.07	0.09	NS	0.05	0.02	0.02	0.04	0.12	0.02	0.05	0.11	0.03	0.02	0.03	0.02	0.03	0.03
C. Application methods																		
Incorporation	2.35	2.40	2.53	1.30	1.49	1.34	0.57	0.68	0.98	0.59	0.60	0.83	0.53	0.55	0.52	1.51	1.57	1.65
Surface applied	2.42	2.47	2.63	1.37	1.59	1.38	0.65	0.79	1.16	0.67	0.69	0.97	0.54	0.58	0.53	1.60	1.62	1.75
SEm±	0.01	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.03	0.006	0.01	0.03	0.009	0.004	0.01	0.008	0.01	0.009
C.D.5%	0.02	0.06	0.08	0.02	0.04	0.02	0.02	0.03	0.10	0.02	0.04	0.09	NS	0.01	NS	0.02	0.03	0.03
C.V. (%)	2.04	5.60	6.54	4.60	5.65	3.25	6.86	10.83	20.24	5.87	15.51	21.86	10.71	5.36	10.82	2.49	4.24	3.30

in case of grains in 1982-83 and 1984-85 each increase in seed rate resulted in a significant increase in N content. In rest of the cases the N content was more at higher seed rate (150 kg/ha) and it differed significantly from 100 and 125 kg/ha seed rates. However, the lower two seed rates were at par with each other.

In case of FYM treatments the N content was affected significantly during all the 3 years with the exception of that in 1982-83 at 10 WAS. In 1982-83 at 6 WAS and in 1983-84 at 10 and 14 WAS the significant increase in N was found only upto F_2 level. At 18 WAS and in grains in 1982-83 and in 1984-85 at 18 WAS and in the straw each increase in FYM level resulted in significant increase in N content. During rest of the years at different stages, 5 and 10 t/ha FYM levels were found to be at par with each other but they recorded significantly lower N content compared to 15 t/ha FYM.

Surface method of FYM application always recorded a higher N content in plant and grains. Only in straw, in 1982-83 and 1984-85 the difference was not significant.

S x F interaction significantly affected the N content at 6 WAS in 1982-83 and 1983-84. The interaction effect data presented in Table 13a show that almost at each level of FYM an increase in seed rate resulted in corresponding increase in N content. However, the significant increase was found to be only upto S_2 at F_1 and F_2 in 1982-83. At F_3, only S_3 differed significantly from S_2. In 1983-84 on the other hand this influence was not consistent. S_3 albeit helped in accumulating highest N content but at F_1 it differed significantly from S_1. At F_2 it differed significantly from S_2 whereas at F_3 it differed significantly from S_1. At F_2 it differed significantly from S_2 whereas at F_3 it differed significantly both from S_1 as well as from S_2.

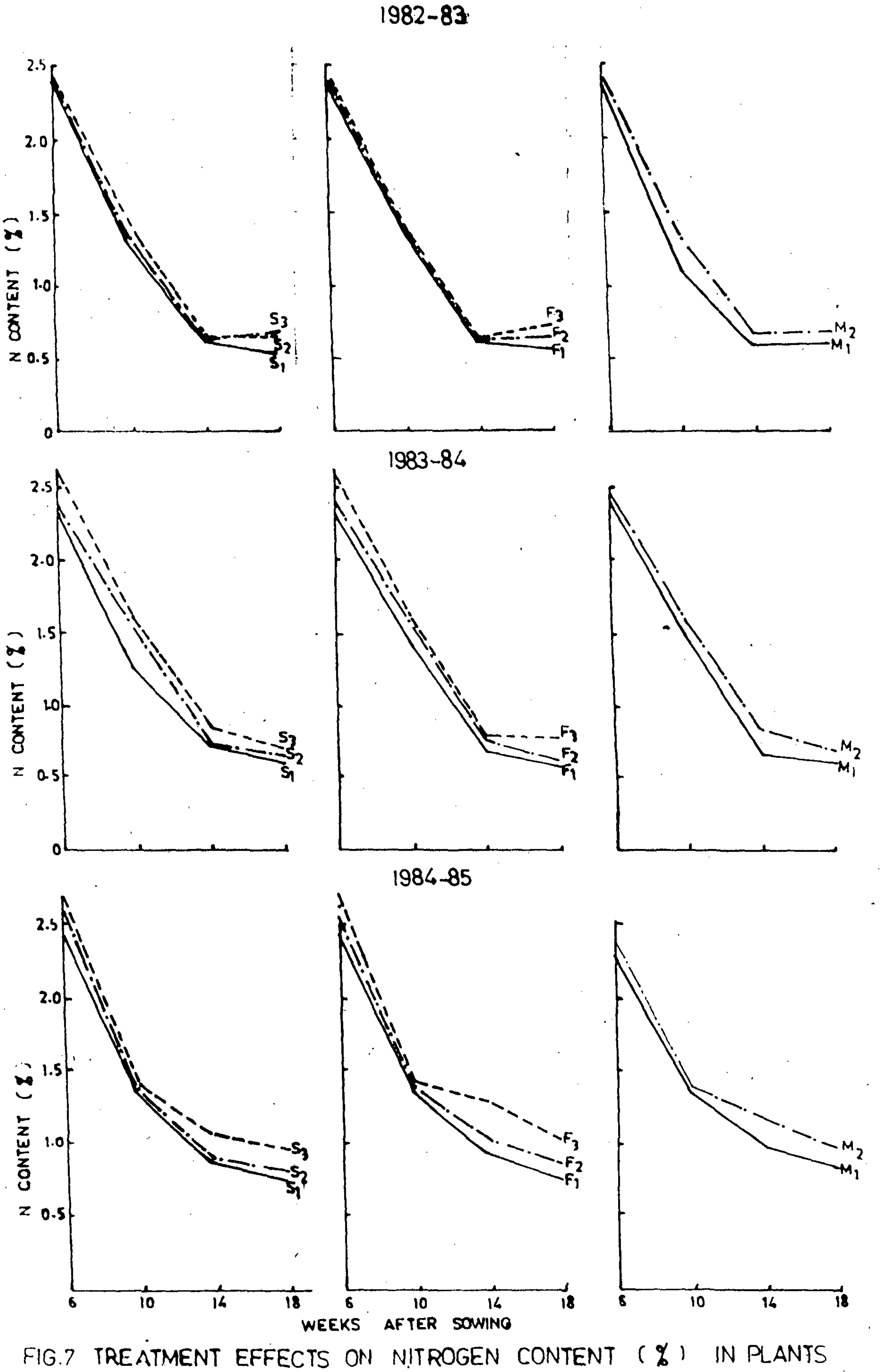


FIG.7 TREATMENT EFFECTS ON NITROGEN CONTENT (%) IN PLANTS

With the exception at S_2 in 1982-83, at each seed rate, 15 t/ha (F_3) FYM resulted in highest N content during both the years and differed significantly from F_1 and F_2 at S_1 in 1982-83 and at S_2 and S_3 in 1983-84. The lower two FYM rates were at par with each other. At S_2 in 1982-83, F_2 recorded the highest N content and differed significantly from F_1 and F_3.

Table 13a. Effect of S x F interaction on N content in plant at 6 WAS (1982-83 and 1983-84)

Seed rates	1982-83			1983-84		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	2.29	2.33	2.40	2.19	2.35	2.43
S_2	2.36	2.44	2.38	2.34	2.31	2.50
S_3	2.38	2.42	2.45	2.43	2.50	2.86
SEm$\pm$		0.02			0.05	
CD5%		0.05			0.15	

Seed rates x FYM levels (S x F) interaction at 10 WAS as found to influence the N content during all the 3 years of experimentation. The interaction effect data presented in Table 13b show that at F_1 during all the 3 years and at F_2 in 1983-84 the significant increase was found upto S_2 level only. At F_2 and F_3 in 1982-83 and at F_3 in 1983-84, S_3 recorded the highest N content and differed significantly from S_1 and S_2 which in turn were at par with each other. Where the difference was not significant at F_2 in 1983-84 at F_3 in 1984-85 each increase in seed rate resulted in a significant increase in N content in plants.

At S_1 and S_2 in 1982-83 the FYM rates viz., F_1, F_2 and F_3 did not differ significantly. At S_3, the highest N content was observed at F_3 which differed significantly only from F_1 and at F_2. In 1983-84 at all the seed rates, F_1 resulted in lowest N content and differed significantly from F_2 and F_3. The

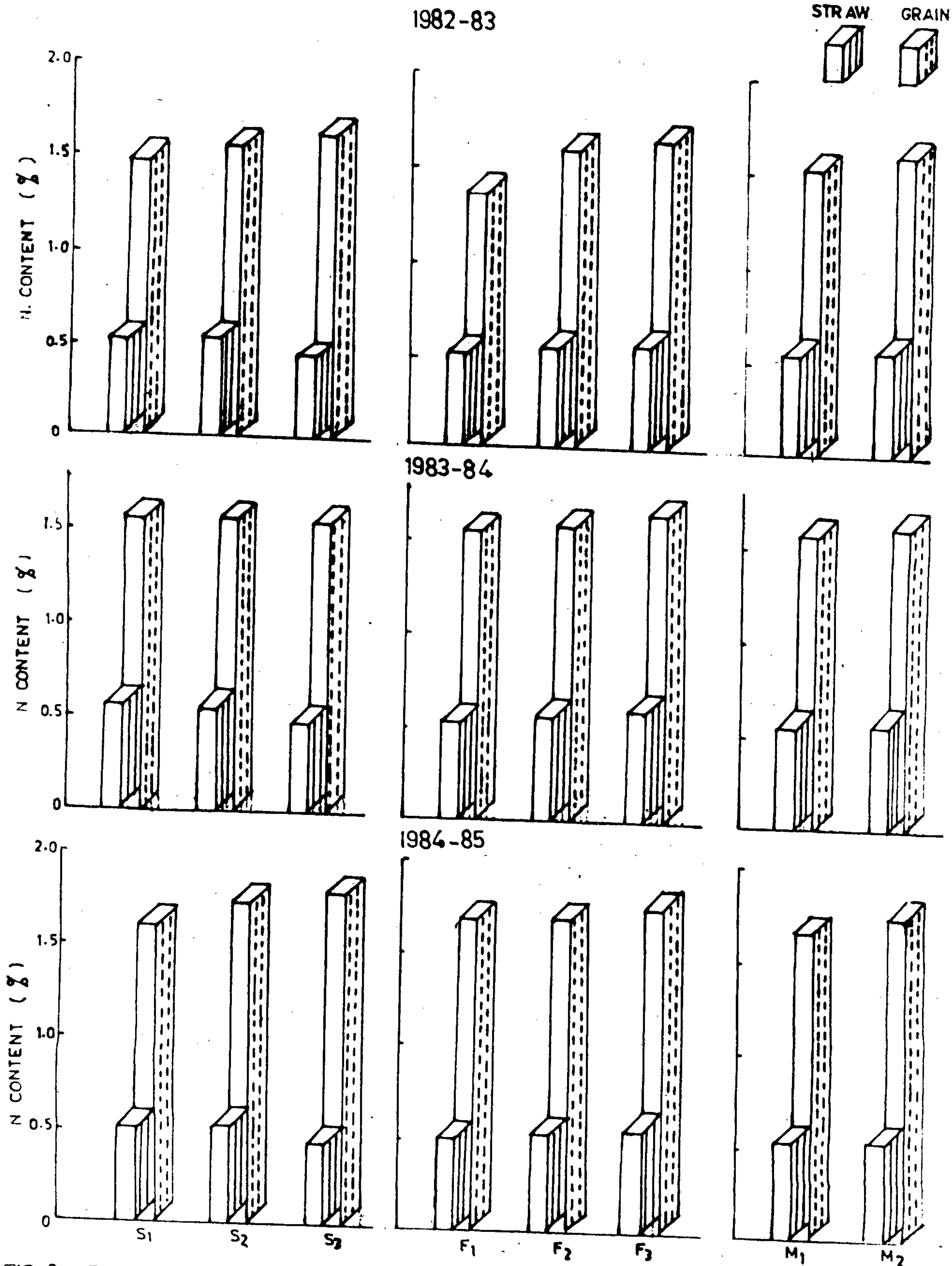


FIG. 8 TREATMENT EFFECTS ON NITROGEN CONTENT (%) STRAW AND GRAIN

latter two FYM rates were at par with each other. In 1984-85 also the same trend was observed at S_1 and S_2. At S_3, however, F_3 which recorded the highest N content differed significantly from F_1 and F_2.

Table 13b. Effect of S x F interaction on N content at 10 WAS (1982-83, 1983-84 and 1984-85)

Seed rates	1982-83			1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	1.26	1.30	1.32	1.33	1.59	1.55	1.27	1.34	1.32
S_2	1.35	1.31	1.28	1.44	1.56	1.55	1.33	1.40	1.40
S_3	1.35	1.42	1.43	1.50	1.61	1.70	1.37	1.36	1.46
SEm±		0.02			0.03			0.02	
CD5%		0.07			0.10			0.05	

The seed rates x FYM levels (S x F) interaction effect at 18 WAS influenced N content significantly in 1982-83 and 1983-84. The interaction effect data presented in Table 13c show that almost at each level of FYM increased seed rate resulted in increased N content. In 1982-83 the significant increase was found only upto S_2 at F_2 and F_3 which remained at par with S_3 and differed significantly from S_1. At F_1 each seed rate differed significantly to one another.

Table 13c. Effect of S x F interaction on N content at 18 WAS (1982-83 and 1983-84)

Seed rates	1982-83			1983-84		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	0.49	0.57	0.65	0.54	0.61	0.66
S_2	0.64	0.63	0.73	0.59	0.59	0.71
S_3	0.58	0.63	0.75	0.60	0.64	0.90
SEm±		0.01			0.04	
CD5%		0.04			0.11	

In 1983-84 at F_1 and F_2, S_3 though recorded higher N content but each seed rate remained at par to one another. However, at F_3, S_3 recorded higher N content and differed significantly from S_1 and S_2 but these two remained at par with each other. At all the seed rates in 1982-83 and at S_2 and S_3 in 1983-84, F_3 resulted in highest N content and differed significantly from lower FYM rates. At S_1 in 1983-84 also F_3 resulted in highest N content but remained at par with F_2 and differed significantly only from F_1.

The Seed rates x FYM levels x Methods of FYM application (S x F x M) interaction effect which was found to be significant at 14 WAS in 1982-83 and 1983-84 (Table 13d) did not have a particular trend at increasing seed rates when compared at different F x M combinations. However, at fixed seed rate, at S_3, F_3M_2 showed the maximum N content in both the years and differed significantly from rest of S x F x M combinations.

Table 13d. Effect of S x F x M interaction on N content at 14 WAS (1982-83 and 1983-84)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	0.53	0.59	0.56	0.62	0.62	0.63
S_2	0.53	0.60	0.58	0.64	0.63	0.64
S_3	0.58	0.57	0.63	0.62	0.69	0.74
SEm±			0.08			
CD5%			0.2			
			1983-84			
S_1	0.50	0.70	0.75	0.78	0.80	0.70
S_2	0.67	0.66	0.71	0.81	0.82	0.74
S_3	0.71	0.74	0.71	0.73	0.81	1.00
SEm±			0.09			
CD5%			0.3			

Some of the other interactions viz., S x F in case of straw and grain in 1983-84, S x M in straw in 1982-83, F x M at 10 WAS in 1983-84 second year, F x M at 18 WAS 1982-83 were found to affect the N content. Since these interactions were significant only for one season and have therefore been given in Appendices XXI, XXII and XXIV, respectively.

4.4.2. Protein content (%) in grain

The data pertaining to the effect of different treatments on protein content (%) in wheat grain have been presented in Table 14 and corresponding analysis of variance given in Appendix XI.

The data embodied in Table 14 show that the seed rate influenced the protein content significantly during all the 3 years as well as when the data were pooled together. In 1982-83 and in the pooled analysis it was seen that each increase in seed rate from 100 to 150 kg/ha resulted in a significant increase in protein content. It is noteworthy that in 1983-84 and 1984-85 also, the protein content was maximum at 150 kg/ha seed rate which in 1983-84 differed significantly from 100 to 125 kg/ha, the latter two seed rates were at par with each other. In 1984-85, 150 and 125 kg seed rates while remaining at par with each other recorded significantly higher protein content compared to that obtained at 100 kg/ha.

Further, while comparing FYM treatments it was seen that maximum protein content was recorded due to 15 t/ha of FYM during all the 3 years and in the pooled analysis as well. Where in 1982-83 and 1983-84 an in the pooled analysis each increase in FYM level brought a significant increase in protein content, in 1984-85, the difference between 5 and 10 t/ha FYM was not found to be significant.

Table 14. Protein content (%) in grain and protein yield (kg/ha)

Treatments	Protein content (%) in grains				Protein yield (kg/ha)		
	1982-83	1983-84	1984-85	Pooled	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)							
100	9.3	9.8	10.0	9.7	180.5	108.0	137.3
125	9.7	9.9	11.0	10.1	217.9	124.3	160.5
150	10.1	10.3	11.2	10.6	239.1	135.6	249.2
SEm±	0.04	0.08	0.07	0.04	7.5	4.7	6.3
C.D.5%	0.1	0.2	0.2	0.1	NS	13.4	18.0
B. FYM rates (t/ha)							
5	9.2	9.7	10.5	9.8	174.0	98.5	151.6
10	9.8	10.0	10.7	10.1	220.9	126.3	180.0
15	10.2	10.3	11.0	10.5	242.6	143.2	215.4
SEm±	0.04	0.08	0.07	0.04	7.5	4.7	6.3
C.D.5%	0.1	0.2	0.2	0.1	NS	13.4	18.0
C. Application methods							
Incorporation	9.4	9.9	10.3	9.9	198.9	114.8	160.3
Surface applied	10.0	10.2	11.0	10.4	226.2	130.5	204.4
SEm±	0.04	0.07	0.08	0.03	6.1	3.8	5.1
C.D.5%	0.1	0.2	0.2	0.1	NS	11.0	14.7
C.V.(%)	2.4	4.3	3.3	2.0	17.3	18.9	17.0

The surface application of FYM showed higher protein content in wheat grain which differed significantly from the incorporation of FYM (M_1).

The pooled S x F interaction effect was found to influence the protein content significantly. The interaction effect data presented in Table 14a show that at each FYM level an increase in seed rate resulted in an increase in protein content. Where each increase in seed rate resulted in a significant increase in protein content at F_3, at F_1 the significant increase was found only upto S_2. At F_2, the significant increase was observed only by increasing the seed rates to 150 kg/ha. On the other hand at each seed rate an increase in FYM rates resulted in corresponding significant increase in protein content.

Table 14a. Effect of S x F interaction on protein content (%) in grain (Pooled)

Seed rates	F_1	F_2	F_3
S_1	9.2	9.7	10.1
S_2	9.9	10.1	10.4
S_3	10.1	10.4	11.0
SEm±		0.08	
CD5%		0.2	

The S x F interaction effect which was also found to be significant in 1982-83 and 1983-84 have been given in Appendix XXI.

4.4.3. Protein production (kg/ha)

The data on protein yield presented in Table 14 and analysis of variance appended in Appendix XII reveal that in 1982-83, the seed rates did not differ significantly. In 1983-84, the significant increase in protein yield was found only upto 125 kg/ha seed rate, but in 1984-85, each increase in seed rate resulted in corresponding significant increase in the protein yield.

Increase in FYM rates increased the protein yield also but the difference was not significant in 1982-83. During rest of the two years each increase in FYM level resulted in corresponding significant increase in protein yield.

FYM application methods did not differ significantly in 1982-83, but in 1983-84 and 1984-85 tne surface application of FYM (M_2) was found significantly superior to incorporation of FYM (M_1) into the soil.

None of the interactions except S x M interaction in 1983-84 influenced protein yield significantly. Since the interaction was significant only during one year, therefore a mention of tnis has been made in Appendix XXII only.

4.4.4. Nitrogen uptake in plant

Data on the uptake of nitrogen by plants at different stages and at harvest (grain + straw) as affected by the main effects of this study are presented in Table 15. The data have also been presented graphically in Fig.9. The corresponding analyses of variance have been given in Appendix XIII.

An examination of Fig. 9 reveals that in general, the nitrogen uptake was very low at 6 to 10 WAS. Thereafter the uptake increased progressively till harvest.

A perusal of the data presented in Table 15 shows that the increase in seed rates resulted in corresponding increase in nitrogen uptake during all the 3 years of experimentation. With the exception of that of 10 WAS in 1984-85 and at 18 WAS in 1982-83 and 1983-84 each increase in seed rate resulted in a significant increase in uptake values. At 10 WAS in 1984-85 and at 18 WAS in

Table 15. Treatment effects on N-uptake (kg/ha) in plants at various stages of crop growth

Treatments	Weeks After Sowing (WAS)														
	6			10			14			18			At harvest		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)															
100	1.10	0.81	1.09	2.5	2.3	2.5	20.3	16.2	26.6	28.6	22.5	32.2	51.4	28.4	36.0
125	1.34	1.05	1.40	3.1	3.0	3.3	22.1	18.5	30.7	35.2	23.4	36.8	63.5	32.6	41.7
150	1.43	1.24	1.62	3.4	3.4	3.4	23.7	21.3	49.8	36.0	28.8	59.5	69.7	47.5	57.0
SEm±	0.01	0.01	0.03	0.04	0.05	0.03	0.3	0.4	1.3	0.4	0.8	1.3	1.8	0.9	1.6
C.D.5%	0.04	0.04	0.07	0.1	0.1	0.1	1.0	1.2	3.8	1.3	2.3	4.1	5.2	2.7	4.7
B. FYM rates (t/ha)															
5	1.20	0.89	1.22	2.8	2.4	2.7	20.7	16.7	28.6	29.1	22.3	34.3	50.7	25.8	38.8
10	1.29	1.03	1.35	3.0	2.9	3.1	22.3	19.0	35.1	32.0	24.1	42.4	63.9	33.7	47.5
15	1.37	1.18	1.54	3.3	3.2	3.6	23.0	20.3	43.4	38.5	30.3	51.8	69.4	39.0	58.4
SEm±	0.01	0.01	0.03	0.04	0.05	0.03	0.3	0.4	1.3	0.4	0.8	1.3	1.8	0.9	1.6
C.D.5%	0.04	0.04	0.07	0.1	0.1	0.1	1.0	1.2	3.8	1.3	2.3	4.1	5.2	2.7	4.7
C. Application methods															
Incorporation	1.21	0.93	1.29	2.8	2.5	2.9	20.2	16.8	31.3	30.2	23.2	38.2	58.1	30.5	43.0
Surface applied	1.37	1.13	1.45	3.3	3.1	3.3	23.9	20.6	40.1	36.2	28.0	47.4	64.6	35.0	53.5
SEm±	0.01	0.01	0.02	0.03	0.04	0.02	0.3	0.3	1.1	0.3	0.6	1.1	1.5	0.7	1.3
C.D.5%	0.03	0.03	0.06	0.1	0.1	0.1	0.8	1.0	3.1	1.0	1.9	3.3	4.2	2.2	3.8
C.V.(%)	6.23	7.91	9.47	6.3	8.6	4.8	7.5	11.5	18.5	6.7	15.6	6.5	14.7	14.3	16.7

1982-83 the significant increase was found only upto 125 kg seed rate/ha. In 1984-85 at 18 WAS, the significant increase was noted only by increasing the seed rate upto 150 kg/ha.

Likewise, in respect of FYM treatments also, during all the 3 years of experimentation at all the stages of crop growth, the N uptake increased with an increase in FYM levels. It was only at 14 WAS in 1982-83 and at 18 WAS in 1983-84 that the two higher and two lower levels of FYM, respectively remained at par. Otherwise each increase in FYM resulted in a significant increase in N uptake.

It was interesting to note that during all the 3 years of experimentation at all the stages of growth the surface application of FYM (M_2) resulted in significantly higher uptake of N as compared to incorporation method (M_1) of FYM application.

In 1982-83 and 1984-85, S x F interaction at 10 and 18 WAS, F x M interaction at 10 WAS in all the 3 years, S x F x M interaction in 1982-83 and 1983-84 at 6, 10 and 14 WAS were found to be significant.

Table 15a presenting the interaction effect of S x F at 10 WAS shows that at each level of FYM, each increase in seed rate resulted in corresponding increase in N uptake. At F_2, in 1982-83 and at F_3 in 1984-85 though the significant increase was noticed only upto S_2 level of seed rate but at rest of the FYM levels each increase in seed rate resulted in a significant increase in N uptake.

Table 15a. Effect of S x F interaction on N uptake (kg/ha) in plants at 10 WAS (1982-83 and 1983-84)

Seed rates	1982-83			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	2.2	2.6	2.7	2.1	2.6	2.8
S_2	3.0	3.2	3.3	3.0	3.2	3.6
S_3	3.2	3.4	3.7	3.2	3.4	3.6
SEm±		0.07			0.06	
CD5%		0.2			0.2	

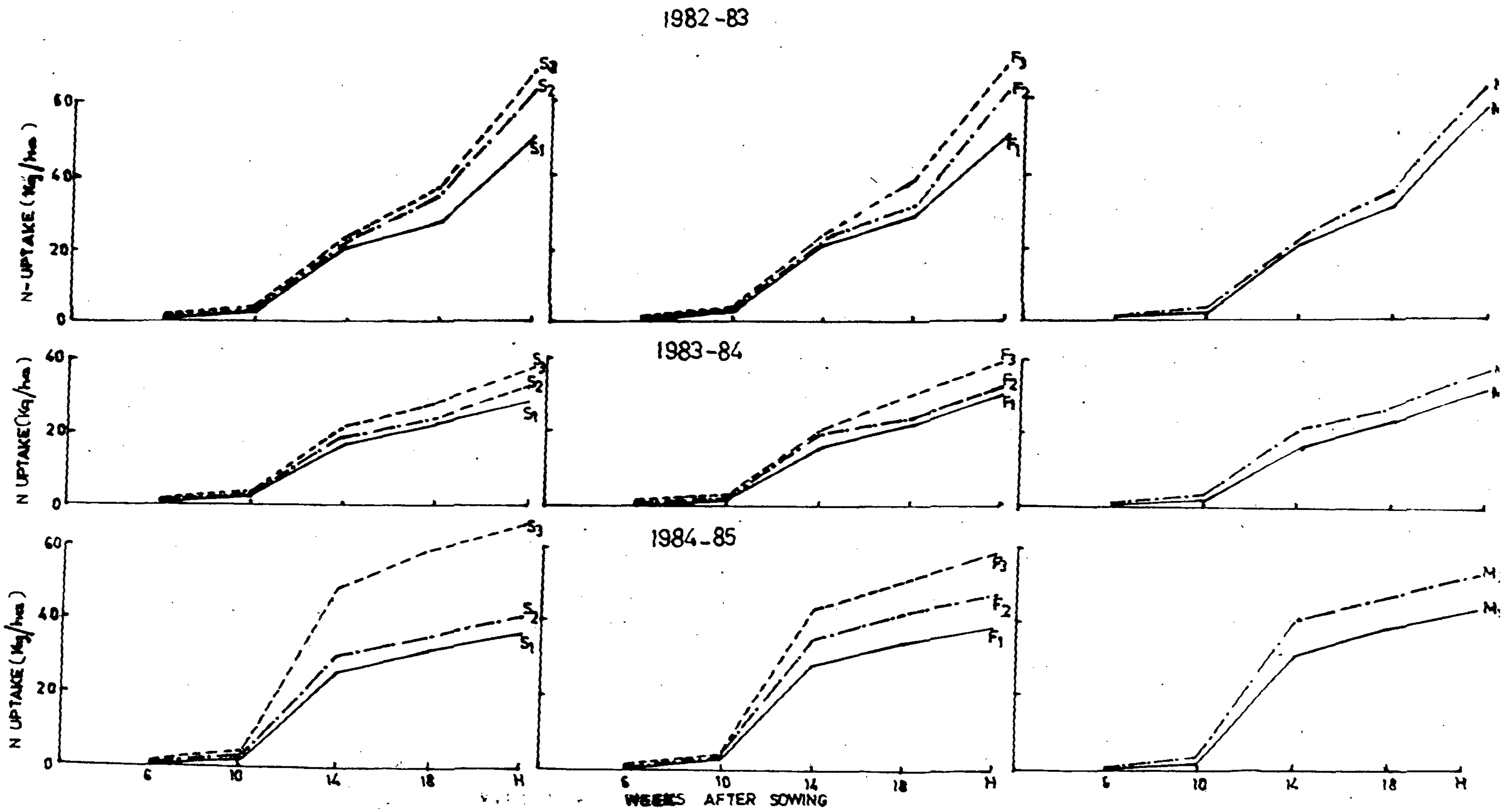


FIG.9 TREATMENT EFFECTS ON N-UPTAKE (Kg/ha)

Likewise at each seed rate an increase in FYM level also resulted in corresponding increase in N uptake. In 1984-85, each increase in FYM resulted in a significant increase in N uptake. In 1982-83 also, F_3 resulted in highest N uptake but it was at par with F_2 at S_1 and S_2 and both (F_2 and F_3) differed significantly from F_1. At S_3, each increase in FYM rate, significantly increased the N uptake and all the FYM rates differed significantly with one another.

The data on the influence of S x F interaction at 18 WAS in 1982-83 and 1984-85 have been given in Table 15b. An examination of data table indicate that at F_3 during both the years each increase in seed rate resulted in significant increase in N uptake. At lower levels of FYM in 1982-83, however, the significant increase was found only upto S_2, whereas in 1984-85 for getting a significant increase the seed rate had to be increased to S_3 level.

Table 15b. Effect of S x F interaction on N uptake (kg/ha) at 18 WAS (1982-83 and 1984-85)

Seed rates	1982-83			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	24.3	28.4	33.5	25.0	35.3	36.0
S_2	32.7	33.6	39.0	29.4	36.0	46.3
S_3	30.1	34.3	42.8	47.5	55.8	73.6
SEm±		0.9			2.8	
CD5%		2.5			8.1	

At fixed seed rates at S_1 and S_3 in 1982-83 and at S_3 in 1984-85, the highest N uptake was obtained where FYM was applied @ 15 t/ha. With these seed rates each increase in FYM levels resulted in significant increase in uptake values. At S_2 in 1982-83 and at S_1 and S_2 in 1984-85 also, F_3 resulted in highest N uptake. However, in 1982-83 F_1 and F_2 remained at par and differed significantly from F_3 but in 1984-85 at S_1, F_3 differed significantly only from F_1 and at S_2, it differed significantly both from F_1 as well as from F_2. The lower two FYM levels in turn remained at par with each other.

F x M interaction at 10 WAS presented in Table 15c indicate that with each method an increase in FYM level resulted in an increase in N uptake during all the 3 years of experimentation. With M_1 in 1982-83 and with M_2 in 1983-84 the significant increase was found only upto F_2 level whereas with M_1 in 1983-84 the significant increase was noted only by increasing the FYM level to F_3. In rest of the cases each increase in FYM level resulted in a significant increase in N uptake.

It was interesting to note that at each level of FYM during all the 3 years of experimentation the surface method of FYM application (M_2) resulted in significantly higher uptake of N.

Table 15c. Effect of F x M interaction on N uptake at 10 WAS (1982-83, 1983-84 and 1984-85)

FYM levels	1982-83		1983-84		1984-85	
	M_1	M_2	M_1	M_2	M_1	M_2
F_1	2.6	2.9	2.3	2.5	2.6	2.8
F_2	2.8	3.3	2.4	3.3	2.8	3.3
F_3	2.9	3.6	2.8	3.5	3.1	3.5
SEm±	0.66		0.07		0.04	
CD5%	0.2		0.2		0.1	

S x F x M interaction was found to affect the uptake of N in plants significantly in 1982-83 and 1983-84. The interaction effect data presented in Table 15d indicate that during both the years $S_3F_3M_2$ recorded the highest N uptake. In 1982, it differed significantlybfrom $S_3F_3M_1$ but was found to be at par with it in 1983-84. During both the years the lowest uptake was recorded with $S_1F_1M_1$.

Table 15d. Effect of S x F x M interaction on N uptake in plant 10 WAS (1982-83 and 1983-84)

Seed rates	M_1			M_2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	1.8	2.4	2.4	2.4	2.7	3.0
S_2	2.8	2.9	3.0	3.2	3.3	3.5
S_3	3.0	3.1	3.2	3.2	3.8	4.2
SEm±			0.2			
CD5%			0.6			
			1983-84			
S_1	1.5	2.0	2.5	2.1	2.9	2.9
S_2	2.5	2.7	2.9	2.6	3.3	3.5
S_3	2.9	2.7	3.0	2.8	3.8	4.1
SEm±			0.5			
CD5%			1.4			

At 14 WAS also S x F x M interaction was found to be significant in 1982-83 and 1983-84. The interaction effect data presented in Table 15e reveal that like that at 10 WAS, at this stage also during both the years $S_3F_3M_2$ resulted in highest N uptake. At this stage it differed significantly

Table 15e. Effect of SxFxM interaction on N uptake in plants at 14WAS(1982-83 and 1983-84)

Seed rates	M1			M2		
	F_1	F_2	F_3	F_1	F_2	F_3
			1982-83			
S_1	16.6	19.6	19.2	21.4	22.0	22.7
S_2	19.1	21.4	20.4	23.1	23.7	24.5
S_3	20.8	20.8	22.9	22.6	27.0	38.3
SEm±			1.0			
CD5%			2.9			
			1983-84			
S_1	10.5	15.6	17.6	17.5	18.2	17.9
S_2	16.2	15.9	17.2	19.6	21.3	20.6
S_3	17.6	19.9	20.1	18.6	23.3	28.2
SEm±			1.3			
CD5%			3.7			

from rest of the SFM treatment combinations. Also, during both the years $S_1F_1M_1$ resulted in lowest N uptake.

The single year interactions viz.,S x F at 6 WAS and at harvest in 1983-84, SxM at 6 WAS in 1984-85, FxM at 6 WAS in 1982-83, FxM at 18 WAS in 1982-83, SxFxM in 1983-84 at 6 WAS also influenced N uptake in plant significantly and have been listed in Appendices XXI,XXII,XXIV and XXVI, respectively.

4.4.5. Phosphorus content (%) in plant

The data pertaining to the influence of main effects on phosphorus content in plants at different stages of growth viz., 6, 10,14 and 18 WAS have been presented in Table 16. The corresponding analyses of variance have been given in Appendix XIV. The data have also been presented diagramatically in Fig.10.

An examination of Fig.10 reveals that the content of phosphorus in the plant fall linearly with the advancement in growth stages during all the 3 years.

A perusal of the data presented in Table 16 show that the seed rates influenced the P content significantly. At 6 WAS in 1983-84 and 1984-85, at 150 kg seed rate/ha the P content was maximum and differed significantly from 100 kg. 125 kg seed rate did not differ significantly from 100 and 150 kg/ha. At all the stages in 1982-83, at 10 WAS in 1983-84 and at 10, 14 and 18 WAS in 1984-85 it was seen that each increase in seed rate resulted in a significant increase in P content. At 14 and 18 WAS in 1983-84, 150 kg seed rate/ha recorded the highest P content, which remained at par with 125 kg seed rate/ha but differed significantly from 100 kg seed rate/ha.

In respect of FYM rates it was observed that invariably each increase in FYM rate resulted in a significant increase in P content but at 14 WAS in

Table 16. Treatment effects on P content (%) in plant at various stages of crop growth

Treatments	Weeks After Soowing (WAS)																	
	6			10			14			18			Straw			Grain		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rate (kg/ha)																		
100	0.156	0.158	0.156	0.123	0.126	0.123	0.097	0.097	0.101	0.074	0.075	0.082	0.023	0.028	0.027	0.172	0.231	0.257
125	0.160	0.163	0.160	0.133	0.138	0.136	0.107	0.112	0.113	0.085	0.089	0.095	0.023	0.028	0.027	0.176	0.259	0.276
150	0.165	0.170	0.165	0.150	0.145	0.146	0.116	0.115	0.124	0.091	0.093	0.103	0.023	0.028	0.027	0.182	0.267	0.179
SEm±	0.001	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.003	0.011	0.019
C.D.5%	0.004	0.009	0.006	0.005	0.007	0.007	0.006	0.006	0.006	0.005	0.006	0.006	NS	NS	NS	NS	0.027	0.046
B. FYM rates (t/ha)																		
5	0.148	0.153	0.146	0.124	0.122	0.122	0.099	0.097	0.107	0.073	0.075	0.088	0.023	0.027	0.025	0.171	0.256	0.281
10	0.159	0.164	0.163	0.134	0.138	0.0134	0.105	0.109	0.114	0.084	0.085	0.093	0.023	0.027	0.026	0.175	0.270	0.227
15	0.174	0.175	0.173	0.147	0.150	0.150	0.118	0.115	0.118	0.094	0.097	0.100	0.025	0.030	0.030	0.185	0.262	0.214
SEm±	0.001	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.003	0.011	0.019
C.D.5%	0.004	0.009	0.006	0.005	0.007	0.007	0.006	0.006	0.006	0.005	0.006	0.006	NS	0.002	0.003	0.009	NS	0.046
C. Application methods																		
Incorporation	0.155	0.158	0.156	0.130	0.131	0.131	0.102	0.104	0.106	0.080	0.081	0.088	0.023	0.026	0.026	0.172	0.244	0.254
Surface applied	0.166	0.169	0.165	0.140	0.142	0.140	0.111	0.111	0.120	0.087	0.090	0.098	0.024	0.030	0.027	0.181	0.261	0.220
SEm±	0.001	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.002	0.010	0.013
C.D.5%	0.003	0.007	0.005	0.004	0.005	0.005	0.005	0.005	0.005	0.006	0.005	0.005	NS	0.003	NS	0.007	NS	NS
C.V.(%)	4.90	9.50	6.12	6.30	8.42	8.44	10.40	9.04	9.22	12.01	12.31	11.06	17.22	9.86	6.85	8.33	18.35	33.31

1982-83 and at 18 WAS in 1984-85, 15 t/ha FYM recorded maximum P content and did not differ significantly from 5 and 10 t/ha levels, but these lower two levels of FYM were at par with each other. On the other hand at 14 WAS in 1983-84 and 1984-85 the significant increase in P content was recorded only upto 10 t/ha FYM level.

Methods of application of FYM influenced the P content significantly at all the stages of crop growth, during all the 3 years of experimentation and it was seen that surface application of FYM recorded higher P content and differed significantly from incorporation method.

Some of the interactions viz., S x F at 6 and 10 WAS in 1982-83 and 1984-85 and at 14 WAS in 1983-84 and 1984-85 were found to be significant.

In S x F interaction at 6 WAS in 1982-83 and 1984-85 presented in Table 16a it was seen that at F_1 in both the years with the increase in seed rate the significant increase in P content was found only upto S_2 level. Where the seed rates did not differ at F_2 FYM level, at F_3, during both the year it was seen that for bringing a significant increase in P content seed rate had to be increased to 150 kg/ha. On the other hand at fixed seed rates at S_1 in 1982-83 and at S_1 and S_2 in 1983-84 it was seen that an increase in FYM rate increased the P content and F_3 resulted in maximum P content but it was at par

Table 16a. Effect of S x F interaction on P content at 6 WAS(1982-83 and 1984-85

Seed rates	1982-83			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	0.139	0.163	0.168	0.137	0.164	0.167
S_2	0.155	0.154	0.168	0.150	0.164	0.167
S_3	0.152	0.162	0.182	0.150	0.163	0.181
SEm$\pm$		0.003			0.004	
CD5%		0.009			0.010	

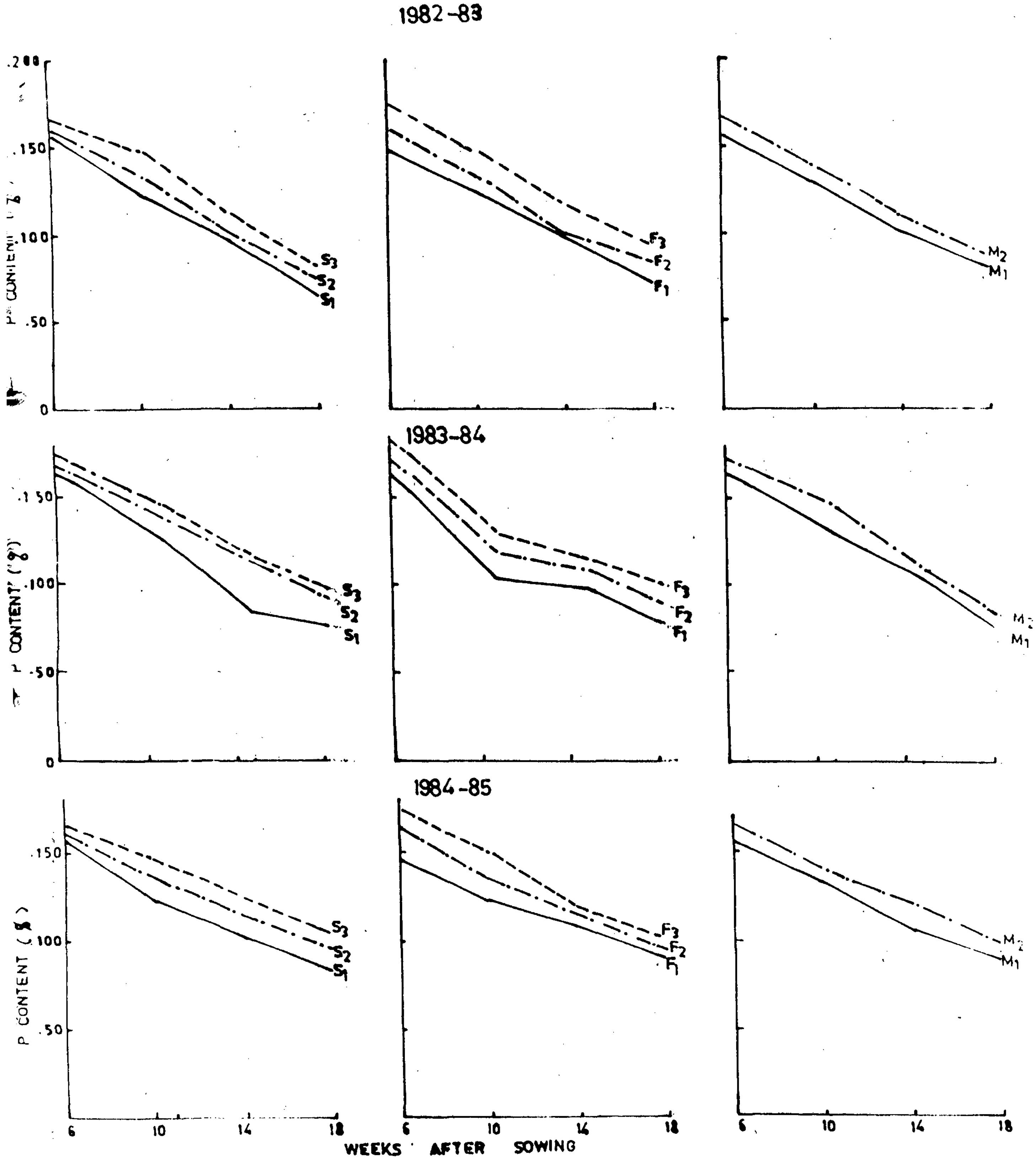


FIG. 10 TREATMENT EFFECTS ON PHOSPHORUS CONTENT (%) IN PLANT

with F_2 and differed significantly only from F_1. At S_2 also in 1982-83, F_3 recorded the higher content of P and differed significantly from F_1 and F_2 but the latter two FYM levels remained at par with each other. At S_3 during both the years however, it was seen that each increase in FYM resulted in a significant increase in P content.

In S x F interaction at 10 WAS in 1982-83 and 1984-85 (Table 16b) it was seen that at F_1 during both the years and at F_3 in 1982-83 the highest P content was recorded at 150 kg seed rate/ha which differed significantly from S_1 and S_2 but the latter two seed rates remained at par with each other. At F_2, in 1982-83, each increase in seed rate resulted in significant increase in P content. At F_3, in 1984-85, the seed rates did not differ significantly from one another. At a constant seed rates at S_1 and S_2 during both the years it was seen that each increase in FYM resulted inccorresponding dsignificant increase in P content in plants. At S_3, the differences were not significant in 1984-85 but in 1982-83 it was seen that though F_3 resulted in highest P content but it was at par with F_2, F_1 and F_2 in turn remained at par with each other.

Table 16b. Effect of S x F interaction on P content at 10 WAS (1982-83 and 1984-85)

Seed rates	1982-83			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	0.110	0.120	0.141	0.106	0.119	0.143
S_2	0.118	0.133	0.148	0.118	0.137	0.153
S_3	0.141	0.149	0.153	0.143	0.142	0.155
SEm±	0.003			0.005		
CD5%	0.009			0.013		

S x F interaction also influenced the P content significantly at 14 WAS in 1983-84 and 1984-85. The interaction effect data presented in Table 16c show that at F_1 and F_3 in 1983-84 and at F_1 and F_2 in 1984-85 though the highest P content was observed at S_3 but the significant increase was noticed only upto S_2 level. At F_2 in 1983-84 and at F_3 in 1984-85 also, S_3 resulted in highest P content but the difference due to seed rates was not significant in the former case. In the latter case also for bringing a significant difference wthe seed rate had to be increased to S_3 level.

Table 16c. Effect of S x F interaction on P content at 14 WAS (1983-84 and 1984-85)

Seed rates	1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	0.068	0.108	0.107	0.082	0.110	0.110
S_2	0.107	0.110	0.118	0.115	0.115	0.110
S_3	0.113	0.112	0.121	0.127	0.117	0.130
SEm$\pm$		0.002			0.004	
CD5%		0.006			0.012	

At a fixed seed rate the effect of FYM at this stage was not consistent over the years. At S_1 during both the years the significant increase in P content was found only upto F_2 level but at S_2 where the differences were not significant in 1984-85, in 1983-84, F_1 and F_2 while remaining at par with each other recorded significantly lesser P content compared to F_3. The same trend was noticed at S_3 in 1983-84 also. In 1984-85, however, F_1 and F_3 while remaining at par with each other recorded significantly higher P content compared to F_2.

Some of the interactions viz., S x F at 18 WAS in 1984-85, F x M at 6 WAS in 1982-83, S x F x M at 14 WAS in 1984-85 which were found to be significant only for one season have been presented in Appendix XXI, XXIV and XXVI, respectively.

4.4.6. P content in straw and grain

P content was determined in straw and grain separately after the harvest and the relevant data have been presented in Table 16. The analyses of variance have been embodied in Appendix XIV.

An examination of the data Table shows that the seed rates did not influence the P content in straw significantly during all the 3 years. In grains also none of the seed rates influenced the P content significantly in 1982-83. In 1983-84 it was observed that 150 kg seed rate/ha recorded highest P content which differed significantly only from 100 kg seed rate/ha. In 1984-85, the trend was reverse in the sense that the P content in grains was more at 125kg seed rate which while remaining at par with 100 kg seed rate differed significantly from 150 kg seed rate/ha.

In respect of FYM treatments it was noticed that the per cent P in straw in 1982-83 and that in grains in 1983-84 was not influenced significantly by FYM levels. In 1983-84 and in 1984-85 in case of straw and in 1982-83 in case of grains the highest P content was obtained at the 15 t/ha FYM which differed significantly from 5 and 10 t FYM/ha. The latter two FYM rates were at par with each other. In 1984-85, the significant increase in P content was noticed only upto F_2 level.

The methods of application of FYM influenced the P content in straw significantly in 1983-84 and in grains in 1982-83 where it was seen that surface method of FYM application recorded significantly higher P content compared to that of incorporation.

S x F interaction effect influenced the P content in straw significantly in 1983-84 and 1984-85. The interaction effect data presented in Table 16d. show that the seed rates did not influence the P content significantly at F_1 and F_2 in 1983-84 whereas at F_3 during the same year and at F_2 and F_3 in 1984-85 for bringing a significant increase in P content the seed rate had to be increased to S_3 level. At F_1, in 1984-85, the highest P content was observed at S_2 which differed significantly from S_1 and S_3. The latter two treatments remained at par with each other.

Table 16d. Effect x S x F interaction on P content in straw (1983-84 and 1984-85)

Seed rates	1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	0.027	0.028	0.027	0.023	0.027	0.023
S_2	0.030	0.028	0.027	0.029	0.025	0.025
S_3	0.022	0.027	0.035	0.027	0.031	0.031
SEm±		0.001			0.002	
CD5%		0.003			0.005	

While comparing the FYM rates at varying seed rates, it was observed that in 1983-84, at S_1 and S_2 and in 1984-85 at all the seed rates none of the FYM rates differed significantly from one another. However, in 1983-84, at S_3 each increase in FYM resulted in a significant increase in P content in straw.

4.4.7. <u>Phosphorus uptake (kg/ha) in plants</u>

The data pertaining to the effect of different treatments on P uptake at different stages of growth by plants have been presented in Table 17. The corresponding analyses of variance have been given in Appendix XV. The treatment effects to show the progressive uptake have also been illustrated graphically in Fig.11.

An examination of Fig.11 reveals that the uptake of P during all the 3 years tended to be more or less sigmoid in nature indicating that the uptake of phosphorus was at a faster pace between 10 to 14 WAS and then increased at a slow pace from 14 to 18 WAS. From 18 WAS to harvest the rate of uptake was very slow.

A perusal of data contained in Table 17 indicates that at all the stages of growth during all the 3 years, phosphorus uptake increased with the increase in seed rates were not the exception of that at 10 WAS in 1984-85 where the differences due to seed rates were not significant. At rest of the stages during all the 3 years, each increase in seed rates resulted in a significant increase in the P uptake. Similarly each increase in FYM rate resulted in an increase in P uptake also. In this case also the differences were not significant at 10 WAS in 1984-85. At 18 WAS and at harvest in 1984-85 for getting a significant increase in P uptake the FYM rate had to be increased to 15 t/ha.

The application methods of FYM also influenced P uptake significantly in all the three years at different stages. The surface application of FYM resulted in higher P uptake and differed significantly from the FYM mixed in the soil, except at 10 WAS in 1984-85 during which the FYM application methods did not differ significantly.

Some of the interaction effects viz., S x F at 14 WAS in 1982-83 and 1984-85, F x M at 6 WAS in 1982-83 and 1983-84 and F x M at 14 WAS in 1983-84 and 1984-85 also influenced the uptake of phosphorus significantly.

In S x F interaction effect in 1983-84 and 1984-85 presented in Table 17a it was seen that in 1983-84 at F_1, S_3 resulted in highest P uptake which

Table 17. Treatment effects on P-uptake (kg/ha) in plant at various stages of crop growth

Treatments	Weeks After Sowing (WAS)														
	6			10			14			18			At harvest		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)															
100	0.074	0.055	0.069	0.24	0.20	0.23	3.34	2.16	3.05	3.73	2.79	3.65	4.30	3.01	3.72
125	0.089	0.072	0.087	0.32	0.27	0.32	3.91	2.77	3.73	4.45	3.50	4.49	5.14	3.86	4.58
150	0.0988	0.081	0.099	0.36	0.29	0.36	4.29	3.14	4.23	5.00	3.75	4.92	5.70	4.22	5.03
SEm±	0.001	0.002	0.002	0.006	0.006	0.07	0.08	0.05	0.07	0.10	0.09	0.12	0.16	0.09	0.13
C.D.5%	0.004	0.005	0.005	0.01	0.01	NS	0.24	0.12	0.22	0.28	0.23	0.31	0.46	0.27	0.32
B. FYM rates (t/ha)															
5	0.076	0.058	0.071	0.26	0.20	0.25	3.48	2.31	3.34	3.67	2.88	4.03	4.20	3.09	4.11
10	0.085	0.070	0.086	0.31	0.26	0.30	3.78	2.71	3.70	4.40	3.31	4.32	5.19	3.64	4.41
15	0.099	0.080	0.098	0.36	0.30	0.36	4.29	3.05	3.97	5.10	3.85	4.70	5.75	4.36	4.81
SEm±	0.001	0.002	0.002	0.006	0.006	0.07	0.08	0.05	0.07	0.10	0.09	0.12	0.16	0.09	0.13
C.D.5%	0.004	0.005	0.005	0.01	0.01	NS	0.24	0.12	0.22	0.28	0.23	0.31	0.46	0.27	0.32
C. Application methods															
Incorporation	0.079	0.061	0.079	0.28	0.23	0.28	3.60	2.53	3.35	4.08	3.10	4.05	4.78	3.41	4.14
Surface applied	0.094	0.078	0.091	0.33	0.28	0.33	4.10	2.86	4.00	4.71	3.60	4.65	5.31	3.98	4.75
SEm±	0.001	0.001	0.001	0.005	0.004	0.05	0.06	0.03	0.06	0.08	0.06	0.09	0.13	0.08	0.09
C.D.5%	0.003	0.004	0.004	0.01	0.01	NS	0.19	0.10	0.18	0.23	0.19	0.25	0.37	0.22	0.26
C.V.(%)	7.2	11.3	9.5	7.9	9.5	10.2	10.8	8.3	10.6	11.3	12.3	12.5	15.8	13.0	12.6

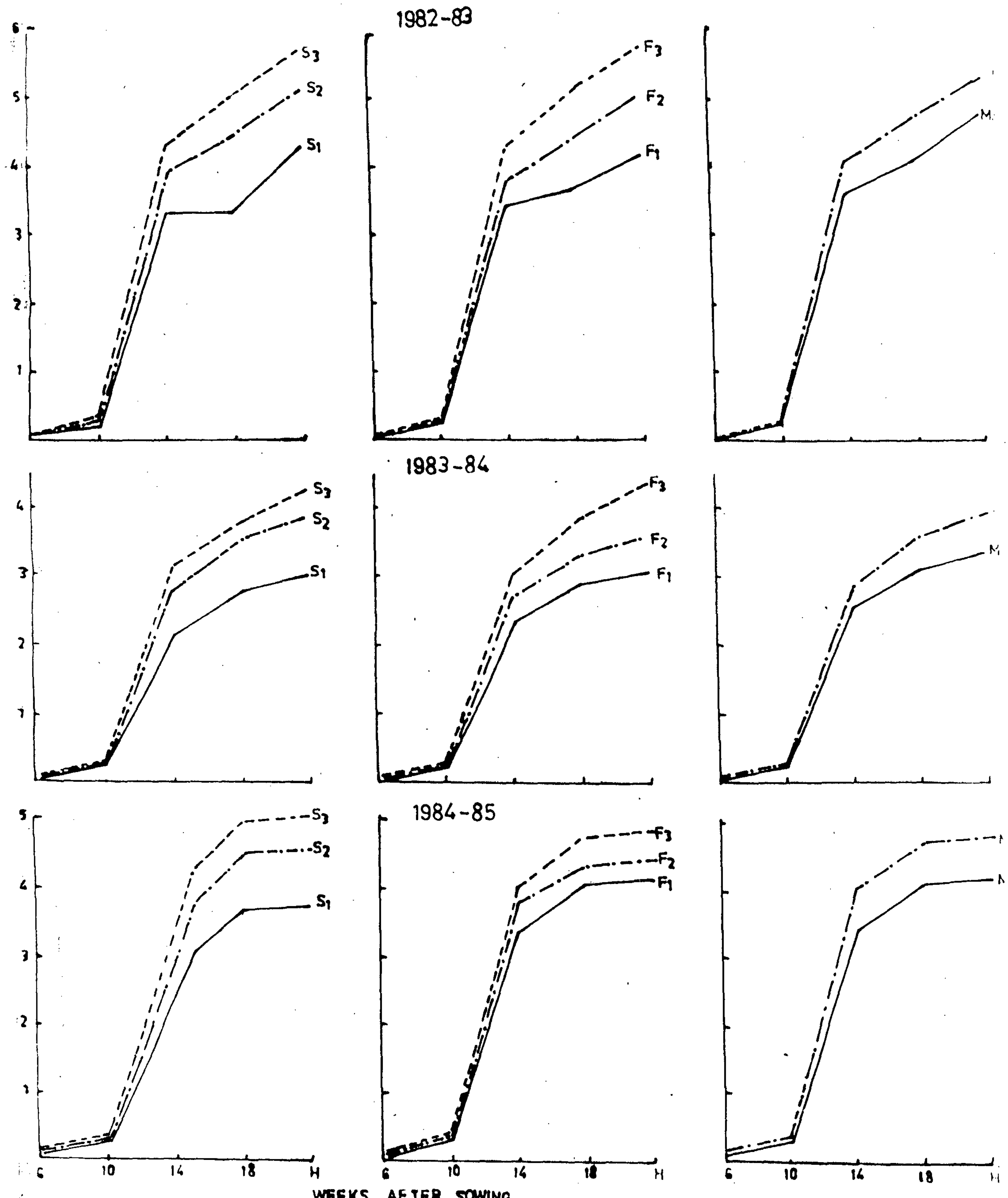
remained at par with S_2 and differed significantly from S_1. Same trend was observed in 1984-85 at F_2. At F_2 and F_3, in 1983-84, each increase in seed rate resulted in a significant increase in P uptake.

Table 17a. Effect of S x F interaction on P uptake at 14 WAS (1983-84 and 1984-85)

Seed rates	1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	1.46	2.39	2.60	2.29	3.28	3.51
S_2	2.61	2.66	3.09	2.68	3.77	3.77
S_3	2.82	3.12	3.47	4.14	4.05	4.53
SEm±		0.09			0.15	
CD5%		0.25			0.45	

In 1984-85 also, at F_1 and F_3, 150 kg/ha seed rate resulted in the highest P uptake and differed significantly from S_1 and S_2. The lower two seed rates remained at par with each other. Further, at fixed seed rates viz., S_1 and S_2 during both the years, F_2 and F_3 while remaining at par with each other recorded significantly higher P uptake compared to F_1. At S_3, during both the years, FYM @ 15 t/ha recorded the highest P uptake but in 1983-84 where each increase in FYM resulted in a significant increase in P uptake in 1984-85, 15 t/ha FYM (F_3) differed significantly only from 10 t/ha (F_2).

The F x M interaction effect at 6 WAS in 1982-83 and in 1983-84 presented in Table 17b shows that in 1982-83 with FYM incorporated in the soil (M_1) to get a significant increase in P uptake the FYM rates had to be increased to F_3 level. In rest of the cases during both the year each increase in FYM rate resulted in a significant increase in P uptake.



11 TREATMENT EFFECTS ON P UPTAKE (Kg/ha)

It was interesting to note that at each level of FYM during both the years the surface method of FYM application resulted in significantly higher P uptake.

Table 17b. Effect of F x M interaction in P uptake at 6 WAS (1982-83 and 1983-84)

FYM levels	1982-83		1983-84	
	M_1	M_2	M_1	M_2
F_1	0.073	0.079	0.053	0.063
F_2	0.078	0.093	0.062	0.067
F_3	0.088	0.110	0.068	0.092
SEm±	0.002		0.002	
CD5%	0.005		0.006	

The F x M interaction in 1983-84 and 1984-85 also influenced the P uptake at 14 WAS (Table 17c). The data in table shows that with both the methods of application of FYM, each increase in the rates of FYM resulted in corresponding significant increase in P uptake.

Table 17c. Effect of F x M interaction on P uptake at 14 WAS (1983-84 and 1984-85)

FYM levels	1983-84		1984-85	
	M_1	M_2	M_1	M_2
F_1	2.25	2.38	3.08	3.60
F_2	2.54	2.87	3.48	3.92
F_3	2.80	3.31	3.48	4.46
SEm±	0.06		0.11	
CD5%	0.18		0.31	

As regards the methods of application of FYM it was seen that at F_1 in 1983-84 the two methods did not differ significantly but in rest of the cases surface application (M_2) always resulted in significantly higher P uptake.

The interactions, S x F at 18 WAS and at harvest in 1984-85, F x M at 10 WAS in 1983-84 and S x F x M at harvest in 1983-84 which were found to be significant only for one year have been presented in Appendix XXI, XXIV and XXVI, respectively.

4.4.8. Potassium content (%) in plants

The data on the potassium content at different stages of growth in plants as influenced by the main effects of the study during the 3 years of experimentation are given in Table 18. The analyses of variance for respective years have been presented in Appendix XV. The data are also illustrated graphically in Fig.12.

An examination of Fig.12 reveals that the content of K during all the 3 years in different treatments slowly decreased from 6 to 10 WAS. The decrease was steep from 10 to 14 WAS. From 14 WAS onwards again the decrease was steady.

A perusal of the data presented in Table 18 indicates that the seed rate treatments did not influence K content significantly at 6 WAS in 1983-84, at 10 WAS in 1983-84 and 1984-85 and at 18 WAS in 1984-85. However, at 6 WAS in 1982-83, it was observed that 150 kg seed rate/ha resulted in the highest K content which differed significantly from 100 kg seed rate/ha but 125 kg/ha seed rate remained at par with 100 and 150 kg/ha. In 1984-85, at 6 WAS, more K content was observed at 150 kg/ha and differed significantly from 100 and 125 kg/ha, the latter two seed rates remained at par with each other. Similar trend was also observed in 1984-85 and in 1983-84 at 14 and 18 WAS, respectively. In 1982-83 at 10 WAS, each increase in seed rate resulted in a significant

Table 18. Treatment effects on K content (%) in plants at various stages of crop growth

Treatments	6 WAS			10 WAS			14 WAS			18 WAS		
	1982 -83	1983 -84	1984 -85	1982 -83	1983 -84	1984 -85	1982 -83	1983 -84	1984 -85	1982 -83	1983 -84	1984 -85
A. Seed rates (kg/ha)												
100	2.35	2.58	2.50	2.13	2.42	2.22	1.15	1.13	1.13	1.12	0.92	0.97
125	2.37	2.60	2.62	2.29	2.44	2.23	1.49	1.32	1.28	1.32	1.01	1.11
150	2.47	2.72	2.82	2.35	2.48	2.30	1.52	1.47	1.89	1.52	1.20	1.65
SEm±	0.04	0.04	0.05	0.05	0.04	0.05	0.04	0.05	0.07	0.04	0.05	0.07
C.D.5%	0.10	NS	0.14	0.14	NS	NS	0.12	0.14	0.17	0.11	0.12	NS
B. FYM rates (t/ha)												
5	2.07	2.30	2.38	1.90	2.07	1.86	1.12	1.15	1.15	1.17	0.84	0.96
10	2.38	2.47	2.55	2.13	2.37	2.22	1.42	1.28	1.37	1.31	1.03	1.22
15	2.74	3.13	3.08	2.74	2.90	2.67	1.62	1.50	1.79	1.49	1.26	1.55
SEm±	0.04	0.04	0.05	0.05	0.04	0.05	0.04	0.05	0.07	0.04	0.05	0.07
C.D.5%	0.10	NS	0.14	0.14	NS	0.13	0.12	0.14	0.17	0.11	0.12	NS
C. Application methods												
Incorporation8	2.30	2.56	2.58	2.18	2.35	2.14	1.32	1.21	1.33	1.29	0.98	1.16
Surface applied	2.50	2.70	2.71	2.33	2.54	2.36	1.45	1.41	1.54	1.35	1.11	1.32
SEm±	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.05	0.03	0.03	0.05
C.D.5%	0.08	NS	0.11	0.11	NS	0.10	0.09	0.11	0.14	NS	0.10	NS
C.V.(%)	7.6	6.6	9.4	10.7	8.2	9.9	14.9	19.0	21.3	15.1	21.0	25.3

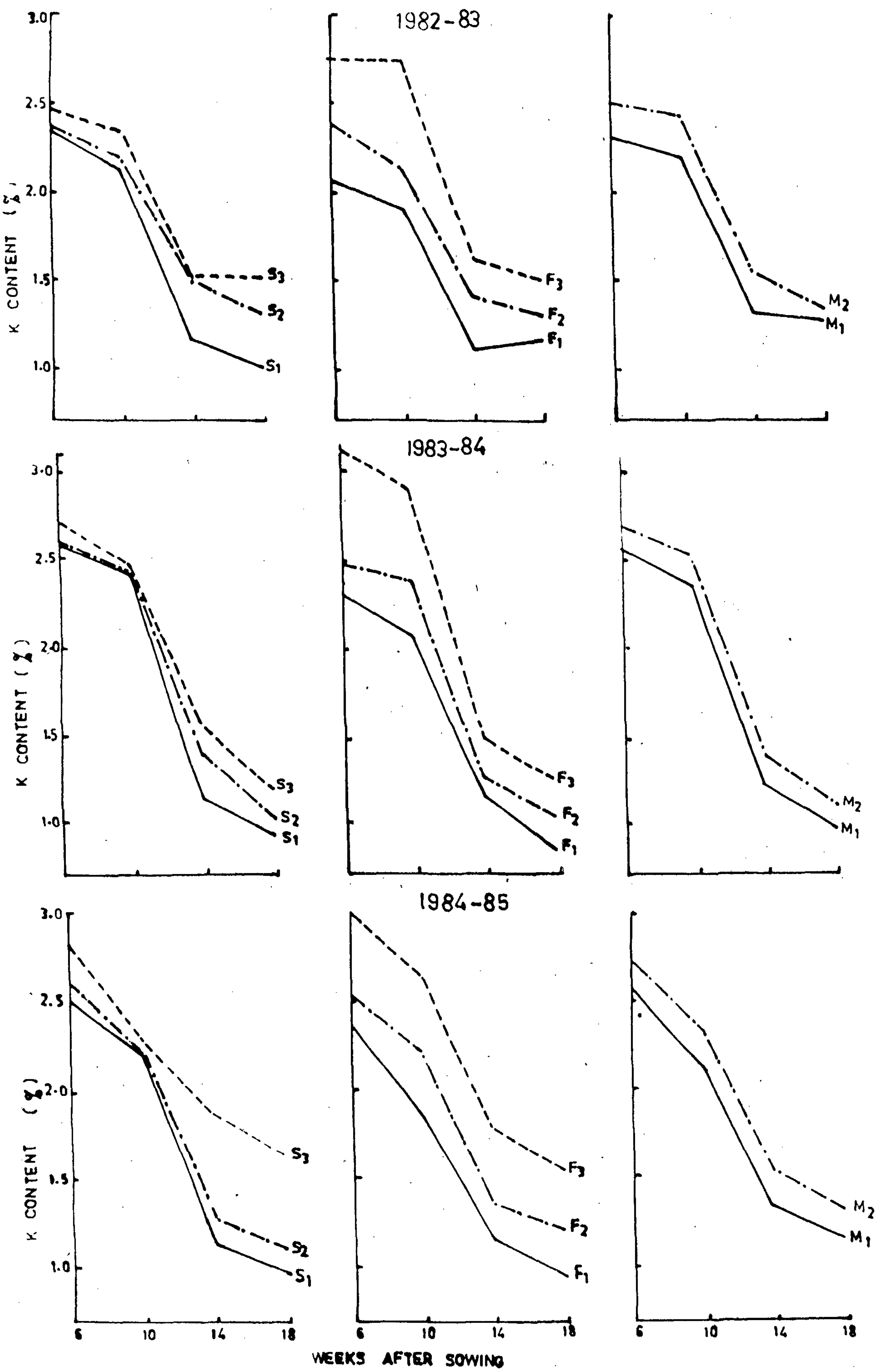


FIG.12 TREATMENT EFFECTS ON K CONTENT (%) IN PLANTS

increase in K content. Similar trend was observed in 1982-83 at 14 and 18 WAS and in 1983-84 at 14 WAS.

In respect of FYM rates it was seen that these treatments did not influence significantly the K content at 6 and 10 WAS in 1983-84 and at 18 WAS in 1984-85. However, at 6 WAS in 1982-83, each increase in FYM rate resulted in a significant increase in K content. More or less a similar trend was observed in most of the cases but at 14 WAS in straw as well as in grain in 1983-84, in straw in 1982-83 and in straw as well as in grain in 1984-85 the FYM application rate had to be increased to 15 t/ha to get a significant increase in K content.

The surface method of FYM application always resulted in higher K content but the difference was not significant at 6 and 10 WAS in 1983-84, at 18 WAS in 1982-83 and 1984-85 in straw in 1982-83 and in grains in 1984-85.

None of the interactions affected the K content in the plant significantly.

4.4.9. Potassium uptake (kg/ha) in plants

The data in respect of K uptake in plants as affected by the main effects of the study at different stages of growth in the 3 seasons have been given in Table 19. The analyses of variance have been given in Appendix XVI. The treatment effects have also been illustrated graphically in Fig.13.

An examination of Fig.13 reveals that in general, the K uptake during three crop seasons in all the treatments was less in early growth stages of plants between 6 and 10 WAS but it got speeded up at 14 WAS. The rate of uptake got slowed down from 14 to 18 WAS and thereafter the uptake values increased at much slower speed.

Table 19- Treatment effects on K-uptake (kg/ha) in plants at various stages of crop growth

Treatments	Weeks After Sowing (WAS)														
	6			10			14			18			At harvest		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85
A. Seed rates (kg/ha)															
100	1.10	0.90	1.10	4.1	3.9	4.3	39.8	26.5	34.1	55.7	33.8	43.2	58.9	35.5	45.1
125	1.33	1.16	4.43	5.5	4.7	5.4	53.6	33.1	42.7	69.5	40.2	52.9	72.3	43.8	54.7
150	1.47	1.29	1.69	5.8	5.0	5.6	56.1	40.0	64.8	83.6	48.2	80.8	86.1	52.3	53.1
SEm±	0.02	0.02	0.04	0.1	0.09	0.1	1.6	1.5	2.1	2.2	1.7	2.8	2.1	2.0	2.8
C.D.5%	0.06	0.06	0.10	0.3	0.2	0.3	4.5	3.9	3.3	3.6	4.9	7.0	6.0	5.0	7.0
B. FYM rates (t/ha)															
5	1.06	0.87	1.17	4.0	3.5	3.9	39.9	26.5	35.8	59.4	32.1	44.3	61.8	34.1	46.1
10	1.28	1.06	1.36	4.8	4.4	5.0	50.6	33.1	45.1	69.0	40.5	57.7	71.4	43.7	59.7
15	1.56	1.42	1.70	6.6	5.8	6.4	58.9	40.0	60.7	80.4	50.1	75.0	84.1	53.8	77.2
SEm±	0.02	0.02	0.04	0.1	0.09	0.1	1.6	1.5	2.1	2.2	1.7	2.8	2.1	2.0	2.8
C.D.5%	0.06	0.06	0.10	0.3	0.2	0.3	4.5	3.9	5.3	6.3	4.8	7.0	6.0	5.0	7.0
C. Application methods															
Incorporation	1.18	0.99	1.31	4.6	4.1	4.6	47.1	29.7	42.5	65.7	37.3	53.4	68.7	40.1	55.3
Surface applied	1.42	1.25	1.51	5.6	5.0	5.6	52.5	36.7	51.9	73.4	44.5	64.5	76.2	47.7	66.7
SEm±	0.01	0.01	0.03	0.09	0.06	0.09	1.3	1.1	1.5	1.8	1.4	2.0	1.7	1.4	2.0
C.D.5%	0.05	0.05	0.08	0.2	0.1	0.3	3.7	3.1	4.3	5.1	4.0	5.7	4.9	4.0	5.8
C.V.(%)	8.2	5.6	12.7	11.9	8.3	11.2	15.8	20.1	19.4	15.6	20.5	20.5	14.5	19.4	19.9

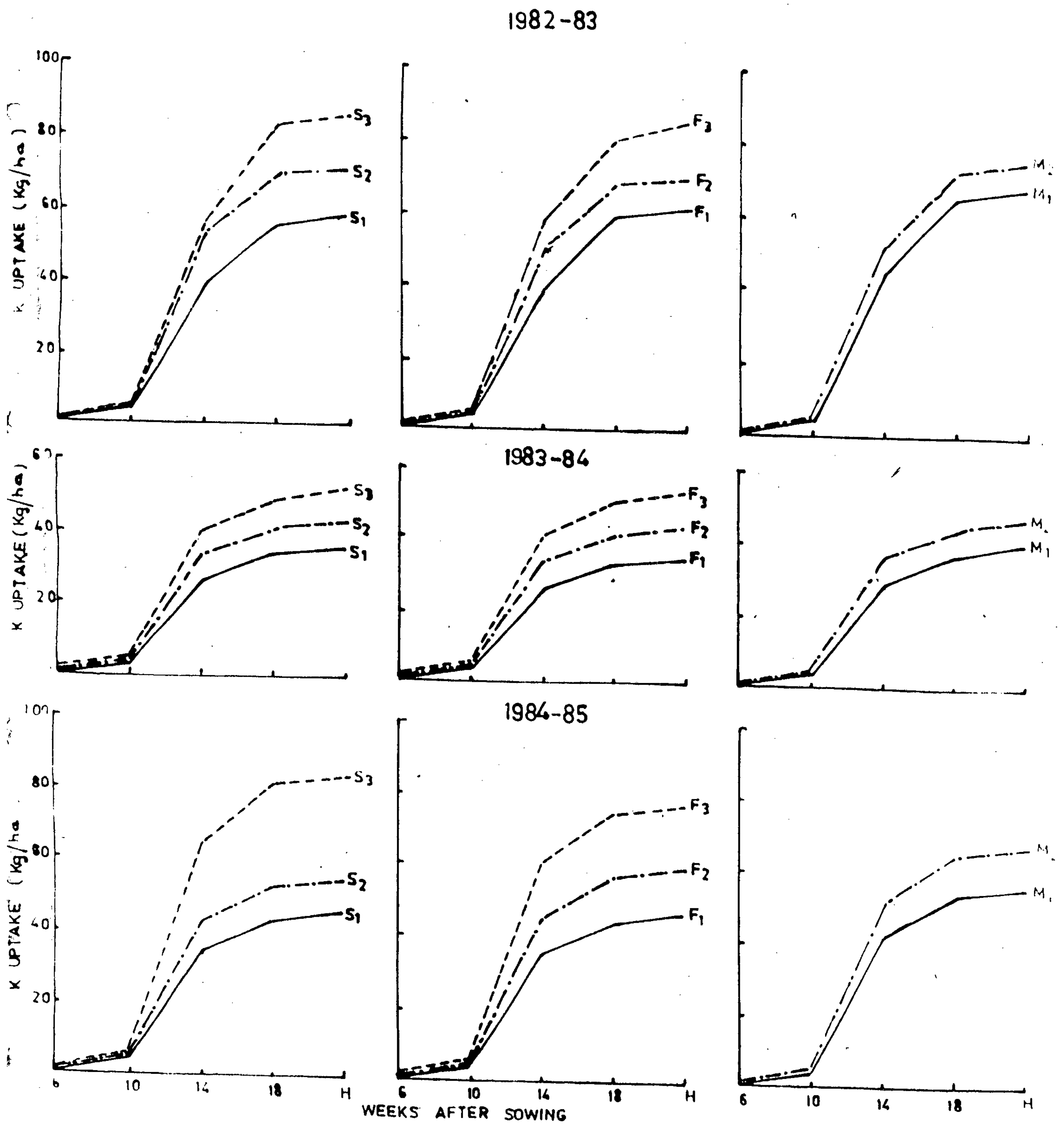


FIG. 13 TREATMENT EFFECTS ON K UPTAKE (Kg/ha)

The data in Table 19 show that with the exception of that of 10 WAS in 1982-83 and 1984-85 and 14 WAS in 1982-83, each increase in seed rate resulted in a significant increase in K uptake throughout the course of the investigation. At these stages the significant increase was observed only upto 125 kg/ha seed rate.

In respect of FYM rates it was noticed that at all the stages of crop growth during the 3 crop seasons each increase in FYM rate resulted in a significant increase in K uptake.

The surface application of FYM was superior to incorporation method and it always resulted in significantly higher uptake of K.

F x M interaction at 6 WAS in 1982-83, and F x M and S x F x M interactions at 10 WAS in 1983-84 because of being significant only for one year have been given in Appendix XXIV, and XXVI, respectively.

4.5. Soil Studies

4.5.1. Soil temperature

With the exception of rainy days soil temperature was recorded daily between 12 noon to 2 P.M. from the start of seed emergence i.e. 13 January to end of February during two crop seasons viz., 1982-83 and 1984-85. Due to rains on 26, 27, 28 and 29 January and on 13, 14, 15, 23 and 24 February in 1983 and on 26 and 27 January and 4 and 20 February in 1985, the observations could not be taken. The study was limited to one replication only. The statistical analysis was therefore, not possible and only the average values based on 3 observations from each plot have been given in Table 20.

An examination of the data presented in Table 20 indicates that with the increase in seed rate the soil temperature in general registered a decline. The highest temperature was recorded at 100 kg seed rate/ha and the lowest at

Table 20 . Treatment effects on soil temperature (°C) in 0-5cm depth from 13 January to 28th February (1983 and 1985).

Dates	Seed rates (kg/ha) 100	125	150	FYM rates (t/ha) 5	10	15	Application methods Incorporation	Surface applied
				1983				
January 13	16.1	15.8	15.0	15.1	15.5	16.3	14.7	16.6
14	18.3	18.0	17.8	17.8	18.1	18.2	17.1	19.0
15	13.0	12.9	12.8	12.6	12.6	13.2	11.9	13.9
16	16.6	16.4	16.2	16.2	16.3	16.7	15.8	17.1
17	18.2	17.4	17.1	17.1	17.4	18.2	16.3	18.8
18	16.8	15.6	15.2	15.4	15.9	16.3	15.1	16.6
19	19.3	18.8	18.1	17.9	18.7	19.5	17.8	19.6
20	21.9	21.5	20.6	21.2	21.3	21.6	20.1	22.6
21	15.7	14.9	14.1	14.4	14.8	15.5	13.9	15.9
22	19.2	18.6	18.0	18.1	18.6	19.1	17.7	19.5
23	17.9	17.4	17.0	16.6	17.5	18.3	16.4	18.6
24	18.7	18.3	17.4	17.6	18.1	18.7	17.1	19.2
25	17.1	16.6	16.3	16.0	16.7	17.4	15.7	17.6
30	16.0	15.0	14.7	14.8	15.1	15.7	14.2	16.3
31	17.9	17.5	16.8	17.0	17.2	17.9	16.4	18.5
February 1	17.1	16.6	16.0	16.3	16.6	16.9	15.5	17.6
2	15.2	14.6	14.4	14.3	14.7	15.0	13.5	15.9
3	18.5	17.8	17.0	17.2	17.7	18.4	16.5	19.0
4.	16.8	16.4	15.6	15.9	16.2	16.6	15.3	17.1
5	17.0	16.4	15.7	15.9	16.3	16.9	15.4	17.4
6	22.8	22.3	21.6	21.6	22.1	23.0	21.1	23.3
7	19.0	18.3	17.2	17.8	18.2	18.5	17.2	19.1
8	23.7	23.1	22.4	22.7	23.0	23.5	22.2	24.0
9	23.2	22.6	21.9	22.4	22.5	22.8	21.7	23.4
10	21.5	21.0	20.2	20.6	20.8	21.3	20.0	21.8
11	21.6	21.2	20.5	20.5	21.3	21.5	20.0	22.1
12	19.5	19.0	18.4	18.5	19.0	19.4	18.1	19.8
16	24.1	23.6	22.9	22.9	23.5	24.1	22.4	24.6
18	25.6	25.1	24.4	24.5	25.1	25.5	24.0	26.1
19	17.1	16.6	15.9	16.0	16.6	17.0	15.6	17.4
20	17.9	17.4	16.7	17.1	17.3	17.6	16.3	18.4

Contd.

Table Contd.

Dates		Seed rates (kg/ha)			FYM rates(t/ha)			Application methods	
		100	125	150	5	10	15	Incorporation	Surface applied
February	21	21.8	21.2	20.6	20.6	21.1	21.9	20.2	22.2
	22	21.3	20.8	20.1	20.1	20.8	21.3	19.8	21.7
	25	22.6	22.2	21.4	21.5	22.0	22.7	21.1	23.0
	26	18.9	18.5	17.8	18.0	18.4	18.7	15.7	19.3
	27	21.3	21.0	20.3	20.6	20.8	21.1	19.8	21.9
	28	14.4	13.9	13.2	13.1	13.8	14.6	12.9	14.8
						1985			
January	13	16.7	16.2	15.6	15.5	16.2	16.7	15.1	17.2
	14	19.9	19.3	18.5	18.8	19.3	19.6	18.1	20.3
	15	16.3	15.7	15.0	15.2	15.7	16.1	14.7	16.6
	16	14.1	13.6	13.0	12.8	13.5	14.3	12.6	14.6
	17	15.4	14.7	14.0	14.3	14.7	15.1	13.6	15.8
	18	17.9	17.3	16.7	17.0	17.2	17.6	16.3	18.3
	19	18.1	17.6	16.9	17.0	17.5	18.1	16.7	18.4
	20	19.0	18.8	18.2	18.2	18.8	19.0	17.6	19.7
	22	19.4	18.9	18.2	18.3	18.9	19.3	17.8	19.8
	23	17.4	16.9	16.2	16.2	16.9	17.4	15.8	17.9
	24	16.7	16.3	15.5	15.3	16.2	17.0	15.1	17.3
	25	17.7	17.4	16.8	16.8	17.1	17.9	16.2	17.4
	28	16.6	16.0	15.2	15.6	15.9	16.3	15.0	16.9
	29	18.5	18.0	17.3	17.5	18.0	18.4	17.0	18.9
	30	19.1	18.6	17.9	18.0	18.6	18.9	17.5	19.5
	31	19.2	18.6	17.9	18.0	18.6	19.1	17.6	19.5
February	1	18.8	18.2	17.5	17.5	18.2	18.7	17.0	19.3
	2	17.6	17.2	16.4	16.7	17.0	17.6	16.0	18.1
	3	19.2	18.7	18.0	18.3	18.6	19.1	17.6	19.7
	5	18.2	17.8	17.0	17.2	17.6	18.2	16.7	18.7
	6	20.9	20.4	19.8	19.8	20.3	21.1	19.3	21.4
	7	18.5	18.0	17.3	17.6	17.8	18.3	16.9	19.0
	8	20.2	19.7	19.3	19.2	19.7	20.3	18.8	20.6
	9	19.3	18.8	18.1	17.9	18.8	19.3	17.8	19.6

Contd....

Table Contd.

Dates		Seed rates (kg/ha)			FYM rates (t/ha)			Application method	
		100	125	150	5	10	15	Incorporation	Surface applied
February	10	20.5	20.0	19.2	19.6	19.8	20.2	18.7	21.1
	11	18.9	18.4	18.0	18.1	18.4	18.8	17.2	19.7
	12	20.4	19.9	19.2	19.2	19.8	20.4	18.6	20.9
	13	19.9	19.3	18.6	18.8	19.3	19.7	18.3	20.2
	14	20.9	20.2	19.4	19.7	20.0	20.8	19.3	21.2
	15	21.4	20.9	20.2	20.4	20.7	21.4	19.4	22.3
	16	22.8	22.2	21.5	21.9	22.1	22.5	21.1	23.3
	17	24.5	24.0	23.2	23.4	23.8	24.2	22.8	24.9
	18	24.9	24.4	23.6	23.6	24.4	24.8	23.0	25.6
	19	24.5	24.0	23.3	23.2	24.0	24.7	22.7	25.2
	21	17.1	16.6	15.8	15.8	16.5	17.3	15.2	17.8
	22	22.0	21.5	20.7	20.9	21.4	22.0	20.5	22.3
	23	22.9	22.4	21.7	21.8	22.4	22.9	21.4	23.3
	24	24.6	24.0	23.3	23.5	23.8	24.6	22.7	25.3
	25	25.3	24.8	24.1	24.2	24.6	25.3	23.3	26.1
	26	21.9	21.4	20.6	20.7	21.3	21.8	20.2	22.3
	27	24.9	24.4	24.1	23.9	24.4	24.4	23.4	25.4
	28	25.9	25.2	24.4	24.6	25.3	25.3	24.0	26.3

150 kg/ha. The decline in soil temperature ranged from 1.3 to 0.8°C in 1982-83 and from 1.3 to 1.1°C in 1984-85.

Contrary to this the increase in FYM rates registered an increase in soil temperature and the increase ranged from 0.8°C to 1.3°C in 1982-83 and from 0.9°C to 2.0°C in 1984-85, as the rate of FYM was increased from 5 to 15 t/ha.

While comparing the methods of application of FYM it may be noticed that surface application of FYM tended to enhance the temperature of soil surface. The increase ranged from 1.9°C to 2.2°C in 1982-83 and from 2.0°C to 2.4°C in 1984-85 compared to that when FYM was mixed in the soil.

4.5.2. Soil moisture content (%)

Observations on soil moisture content in 0-15 cm soil depth were taken after 7 days of each rainfall on different dates and at harvest during the 3 crop seasons. In this manner, there were at least six observations which were common during each year. The data were analysed statistically and hence given in Table 21. The corresponding analyses of variance have been given in Appendix XVIII.

An examination of data table indicates that in general the soil moisture content was high when a low seed rate of 100 kg/ha was used. However, these differences due to seed rates were not significant during the 2nd and 4th observation in 1984-85, 5th observation in 1982-83 and at harvest in 1983-84. During 1st, 2nd and 3rd observation in 1983-84, 1st observation and at harvest in 1984-85 and 2nd observation in 1982-83, 100 kg seed rate/ha which resulted in highest soil moisture content differed significantly from 125 and 150 kg seed rate/ha. The latter two seed rates were at par with each other. During Ist observation in 1982-83, 3rd observation in 1984-85 and during 4th and 5th

Table 21. Treatment effects on soil moisture content(%) in 0-15 cm soil depth of 7 days after each rain

Treatments	I			II			III			IV			V			At harvest		
	5.1. 1983	1.1. 1984	14.1 1985	22.1 1983	29.1. 1984	11.2. 1985	12.2. 1983	10.2. 1984	27.2. 1985	14.3 1983	24.3. 1984	31.3. 1985	7.5. 1983	4.5. 1984	9.5. 1985	29.5. 1983	22.5. 1984	21.5 1985
	1982 -83	1983 -84	1984 -85	1982 -83	1983 -84	1984 -85	1982 -83	1983 -84	1984 -85	1982 -83	1983 -84	1984 -85	1982 -83	1983 -84	1984 -85	1982 -83	1983 -84	1984 -85
A. Seed rates (kg/ha)																		
100	25.7	22.8	27.4	25.1	24.8	25.4	22.8	22.3	27.0	20.8	20.3	27.1	22.5	23.4	21.4	12.1	12.8	11.7
125	25.1	22.2	26.1	23.3	23.5	25.0	22.1	19.9	26.7	20.2	19.3	26.8	22.0	23.2	20.8	11.4	12.2	10.6
150	23.1	21.9	25.5	23.8	22.7	24.7	21.3	18.7	25.2	19.7	18.0	26.5	21.9	21.9	20.0	10.9	11.9	10.0
SEm±	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.1	0.2	0.3	0.3	0.3
C.D.5%	0.8	0.7	1.1	0.9	0.9	NS	0.8	1.2	0.9	0.8	1.1	NS	NS	0.4	0.5	0.7	NS	0.8
B. FYM rates (t/ha)																		
5	23.9	20.4	25.6	22.6	22.6	24.4	21.0	19.7	25.2	19.8	18.5	25.7	21.3	22.7	20.2	9.9	10.4	10.4
10	24.4	22.7	26.7	23.3	23.9	24.9	22.2	19.4	26.7	20.0	19.0	27.0	22.0	22.9	20.5	11.8	12.8	10.5
15	25.6	23.8	26.8	25.6	24.7	26.0	23.1	21.9	27.2	21.1	20.1	27.7	23.1	23.1	21.7	12.9	13.9	11.6
SEm±	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.1	0.2	0.3	0.3	0.3
C.D.5%	0.8	0.7	NS	0.9	0.9	0.9	0.8	0.8	0.9	0.8	0.1	1.2	0.8	0.8	0.5	0.8	0.7	0.8
C. Application method																		
Incorporation	24.0	21.4	25.5	22.9	22.8	24.0	21.4	19.3	25.6	19.3	18.4	25.9	21.3	21.8	20.1	10.7	11.4	10.3
Surface applied	25.2	23.2	27.3	24.8	25.0	26.0	22.9	21.4	27.2	21.1	20.0	27.7	23.0	23.9	21.4	12.2	13.2	11.3
SEm±	0.2	0.2	0.4	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.1	0.1	0.2	0.2	0.2
C.D.5%	0.7	0.6	0.9	0.7	0.7	0.8	0.7	0.9	0.7	0.7	0.9	1.0	0.7	0.4	0.5	0.6	0.6	0.6
C.V.(%)	6.0	5.7	7.4	6.5	7.0	6.8	6.8	10.3	5.8	7.2	10.6	7.7	6.6	3.6	4.9	11.9	10.4	12.8

observation in 1983-84 the soil moisture content in lower two seed rates was statistically similar but was significantly higher than that in 150 kg seed rate/ha.

During 5th stage in 1984-85 each increase in seed rate resulted in significant decrease in soil moisture content.

Contrary to the effect of seed rates the soil moisture content was highest where FYM was applied at the rate of 15 t/ha. During Ist observation and at harvest in 1983-84 and at harvest in 1982-83, each increase in FYM rate resulted in a significant increase in soil moisture content. Where the differences due to FYM rates during Ist observation in 1984-85, and during 5th observation 1983-84, the differences due to FYM rate were not significant in rest of the observations during different years. It was seen that 15 t/ha FYM always resulted in significantly higher soil moisture content compared to 5 t/ha.

It was interesting to note that surface application of FYM always resulted in significantly higher soil moisture content compared to incorporation method during all the observations, during different years of experimentation.

S x F interaction in Ist observation in 1983-84 and 1984-85 and at harvest during all the 3 years of experimentation influenced the soil moisture content significantly.

S x F interaction during Ist observation presented in Table 22a reveals that with the exception at F_1 in 1983-84, at rest of the FYM levels, the lower seed rate (S_1) resulted in higher soil moisture content. At F_3, during both the years, it resulted in significantly higher soil moisture content compared to S_2 and S_3. The latter two seed rates were at par with each other. At F_2, 1983-84, it differed significantly only from S_2. At F_1, during the same year, S_2 resulted in higher moisture content compared to S_1 and S_3 whereas the differences were not significant at this level of FYM in 1984-85.

Table 22a. Effect of S x F interaction on soil moisture content during 1st observation (1983-84 and 1984-85)

Seed rates	1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	19.6	23.6	25.3	26.2	27.0	29.1
S_2	22.0	20.7	23.8	25.1	28.4	25.1
S_3	19.3	23.5	22.7	25.2	24.5	26.4
SEm±		0.5			0.8	
CD5%		1.4			2.3	

With the increase in FYM rates, in general, there was an increase in soil moisture content but in some cases, the significant increase was only upto F_2 level whereas in some cases to get a significant increase the FYM level had to be increased upto F_3 level. The FYM levels however, did not differ significantly from one another at S_1 in 1983-84, and at S_3 in 1984-85.

The same (S x F) interaction effect that influenced the soil moisture content at harvest during all the 3 years of experimentation has been presented in Table 22b.

Table 22b. Effect of S x F interaction on soil moisture content at harvest (1982-83, 1983-84 and 1984-85)

Seed rates	1982-83			1983-84			1984-85		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
S_1	10.2	12.8	13.2	9.6	13.6	15.3	12.3	10.2	12.1
S_2	10.8	10.4	12.7	12.0	10.7	13.7	10.5	10.3	11.5
S_3	8.8	11.9	12.3	9.5	13.5	12.7	9.0	9.9	11.0
SEm±		0.5			0.5			0.5	
CD5%		1.6			1.4			1.6	

At harvest, the soil moisture content almost approached the permanent wilting point and therefore, the effect due to different seed rates was not consistent during the 3 different years. While examining the effect of FYM rates at different seed rates the general trend was that the higher rates of FYM tested brought comparatively higher soil moisture content, a few exception during one of the other year notwithstanding.

Some of the interactions viz., S x F and S x F x M during 2nd observation in 1982-83, which influenced the soil moisture content only for one year have been given in Appendix XXI and XXVI, respectively.

4.6. Physico-chemical properties

Data pertaining to the effect of different treatments on soil reaction (pH), bulk density (B.D.), available nitrogen, phosphorus and potassium, total nitrogen and organic carbon (%) in soil left after the harvest of crop after each season have been presented in Table 22. The corresponding analyses of variance have been given in Appendix XIX.

4.6.1. Soil pH

As regards the change in soil pH it was observed that seed rates did not show a particular trend but in respect of FYM rates, it was seen that an increase in FYM resulted in corresponding decrease in soil pH. The surface method of FYM application registered a marginal decline in soil pH.

4.6.2. Bulk density

Seed rates did not influence significantly the bulk density during any of the years. In respect of FYM rates, it was noted that the increasing rates of FYM decreased the bulk density. The highest rate of FYM (15 t/ha) recorded the minimum bulk density. In 1982-83, it differed significantly from 5 and 10 t/ha FYM and in 1983-84 while remaining at par with 10 t/ha differed significantly only from 5 t/ha. In 1984-85, however, each increase in FYM resulted in significant decrease in bulk density. The surface application of FYM always

Table 22. Treatment effects on soil physico-chemical properties at harvest

Treatments	pH			Bulk Density			Available N			Available P			Available K			Total N			Organic carbon		
	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	1984-85	1982-83	1983-84	198[illegible]
A. Seed rates (kg/ha)																					
100	5.32	5.35	5.43	1.342	1.285	1.313	436.2	394.1	388.9	23.7	21.8	17.3	208.5	201.2	214.2	989.6	1023.5	1070.6	0.68	0.65	0.57
125	5.31	5.37	5.48	1.346	1.296	1.316	435.0	401.4	386.8	21.2	20.0	17.0	207.7	200.5	213.2	886.6	1009.6	1007.5	0.65	0.63	0.56
150	5.29	5.40	5.43	1.347	1.298	1.319	434.6	394.0	377.9	20.5	19.1	16.3	202.8	196.4	204.0	821.1	1023.9	949.5	0.65	0.61	0.54
SEm±	-	-	-	0.004	0.005	0.003	7.4	9.5	8.3	0.6	0.6	1.6	4.2	6.5	6.4	11.6	10.9	11.8	0.01	0.02	0.01
C.D.5%	-	-	-	NS	NS	NS	NS	NS	NS	1.9	1.5	NS	NS	NS	NS	33.2	31.0	33.5	NS	NS	NS
B. FYM rates (t/ha)																					
5	5.42	5.48	5.50	1.357	1.508	1.331	421.2	382.0	375.7	19.2	17.6	16.4	201.5	192.4	205.0	862.4	903.8	923.0	0.56	0.59	0.51
10	5.27	5.37	5.48	1.350	1.289	1.315	432.5	398.6	379.2	21.7	21.0	17.2	202.2	197.1	206.9	886.3	961.8	1033.5	0.68	0.62	0.57
15	5.22	5.27	5.36	1.328	1.283	1.303	452.2	408.9	398.7	24.6	22.5	17.0	215.3	208.5	219.5	948.1	1071.4	1071.0	0.74	0.67	0.61
SEm±	-	-	-	0.004	0.005	0.003	7.4	9.5	8.3	0.6	0.6	1.6	4.2	6.5	6.4	11.6	10.9	11.8	0.01	0.02	0.01
C.D.5%	-	-	-	0.010	0.011	0.008	21.1	NS	NS	1.9	1.5	NS	12.1	NS	NS	33.2	31.0	33.5	0.04	0.05	0.02
C. Application methods																					
Incorporation	5.33	5.38	5.45	1.356	1.299	1.324	429.7	392.0	374.4	21-0	19.3	16.9	109.7	194.6	209.2	841.5	919.5	951.1	0.66	0.59	0.54
Surface applied	5.28	5.36	5.44	1.334	1.287	1.309	440.9	401.0	394.7	22.7	21.3	16.8	213.0	204.1	211.7	956.7	1051.8	1067.3	0.66	0.67	0.58
SEm±	-	-	-	0.002	0.003	0.002	6.0	7.7	6.7	0.5	0.4	1.3	3.4	5.3	5.2	9.5	8.9	9.6	0.01	0.01	0.00
C.D.5%	-	-	-	0.008	0.009	0.007	NS	NS	19.2	NS	1.2	NS	9.9	NS	NS	27.1	25.3	27.4	NS	0.04	0.02
C.V.(3)	-	-	-	1.2	1.5	1.1	8.4	11.7	10.5	15.6	12.7	20.2	10.1	16.1	15.0	6.3	5.4	5.7	11.6	13.6	8.5

recorded a lower bulk density which differed significantly from the incorporation method.

S x F x M interaction in 1984-85 that influenced bulk density has been presented in Appendix XXVI.

4.6.3. Available soil nitrogen

A perusal of data on available soil N also presented in Table 22 indicates that during all the 3 years, the available soil nitrogen after the harvest of the crops was not influenced significantly due to seed rates. In respect of FYM treatments, it was observed that in 1983-84 and 1984-85 these also did not influence the available soil N significantly. But in 1982-83, FYM applied @ 15 t/ha recorded the highest available soil nitrogen which, however, differed significantly from 5 t/ha only. While comparing the methods of FYM application it was seen that though surface application resulted in higher available soil N but the difference was significant only in 1984-85.

4.6.4. Available phosphorus

The data pertaining to the effect of different treatments on available soil phosphorus left after the harvest of the crops have been presented in Table 22. An examination of the data shows that the seed rates did not influence the available P in soil significantly after the harvest in 1984-85. However, in 1982-83 it was observed that each increase in seed rate recorded a significant decrease in available soil P. In 1983-84 the decrease was significant only upto S_2 level 125 kg seed rate/ha.

In respect of FYM rates it was observed that in 1984-85 the available soil P was not influenced significantly by FYM rates. In 1983-84 whereas in 1982-83 each incfease in FYM level resulted in a significant increase in available soil P. The increase in 1983-84 was significant only upto 10 t/ha.

The methods of application of FYM in 1982-83 and 1983-84 did not influence the amount of soil available P significantly. However, in 1983-84 it was observed that surface application of FYM recorded significantly more available P in comparison to the incorporation of FYM in the soil.

The S x M interaction in 1983-84 and 1984-85 influenced the soil available P after harvest significantly. The data have been presented in Table 22a. The interaction effect data table indicates that the seed rates with either of methods did not influence the available soil P in 1984-85, but in 1983-84 the higher amount of available soil P was observed at S_1 with both the methods. With M_1, S_1 differed significantly from S_2 and remained at par with S_3 but with M_2, S_1 and S_2 while remaining at par with each other recorded significantly higher available soil P as compared to S_3.

Table 22a. Effect of S x M interaction on available soil P after harvest (1983-84 and 1984-85)

Seed rates	1983-84		1984-85	
	M_1	M_2	M_1	M_2
S_1	20.9	22.8	16.4	18.3
S_2	17.8	22.3	14.7	19.3
S_3	19.3	19.0	19.7	12.9
SEm±	0.7		2.3	
CD5%	2.1		6.5	

The effect of methods of application at different seed rate was not consistent over the two years. Where at S_2, M_2 resulted in higher available soil P in 1983-84 and differed significantly from M_1, in 1984-85 the difference was not significant. On the other hand, at S_3, in 1983-84 the difference due to two application methods was not significant but in 1984-85 the surface method of application (M_2) resulted in significantly lower available soil P compared to incorporation method (M_1). At S_1 the two methods did not differ significantly during both the years.

Single year S x F interaction in 1983-84 and F x M in 1982-83 influenced available P content in soil and presented in Appendix XXI and XXIV, respectively.

4.6.5. Soil available potassium

A perusal of data on available soil K presented in Table 23 shows that the seed rates did not influence significantly the available K in soil after the harvest of the crop during any of the crop seasons.

The FYM rates, in 1983-84 and 1984-85 also did not influence the soil available K significantly. However, in 1982-83, FYM applied @ 15 t/ha which recorded the highest available K, differed significantly from 5 and 10 t/ha rate of FYM application. The latter two rates remained at par with each other.

The surface application of FYM resulted in higher soil available K but the difference was found to be significant only in 1982-83.

F x M interaction influenced the available soil K significantly in 1982-83. Being significant only for one year, the data therefore, have been given in Appendix XXIV.

4.6.6. Total soil nitrogen

Data on total soil nitrogen reveal that in 1982-83 and 1984-85 increase in seed rates, consistently and significantly decreased the total soil nitrogen. In 1983-84, however, the differences were not significant between 100 and 125 kg seed rate/ha.

In respect of FYM rates, it was seen that in 1983-84 and 1984-85 each increase in FYM rates resulted in a significant increase in total soil N. In

1982-83 also, 15 t/ha FYM resulted in highest total soil N and it differed significantly from 5 and 10 t/ha but the latter two FYM rates remained at par with each other.

During all the 3 years the highest total N after harvest of wheat was due to the surface application of FYM which was significantly higher than incorporation method (M_1).

The interaction effect of S x F in 1982-83 and 1983-84 and S x M interaction in 1983-84 and 1984-85 influenced the total soil N significantly.

S x F interaction effect presented in Table 22b indicates that in general, the lower seed rates had higher total soil N almost at all the FYM levels. S_1 recorded the highest total soil N at F_3 in 1982-83 but remained at par with S_2. Both of them (i.e. S_1 and S_2) however, recorded significantly higher total soil N when compared with S_3. Contrary to this, the differences due to seed rates were not significant and F_3 in 1983-84. At F_1 in 1982-83, S_1 and S_3 while remaining at par with each other recorded significantly higher total N compared to that at S_2. While comparing the FYM rates, with the exception of that at S_3 in 1982-83, each increase in FYM rates resulted in an increase in total soil N. Where the increase at S_1 in 1982-83 and in 1983-84, at S_2 in 1983-84 was significant only upto F_2 level, at S_2 in 1982-83 and at S_3 in 1983-84 each increase in FYM rate resulted in a significant increase in total soil N.

Table 22b. Effect of S x F interaction on total soil N after harvest (1982-83 and 1983-84)

Seed rates	1982-83			1983-84		
	F_1	F_2	F_3	F_1	F_2	F_3
S_1	915.4	997.9	1035.4	946.9	1024.5	1085.8
S_2	771.5	916.8	1001.5	954.0	1027.8	1065.5
S_3	874.8	764.7	814.0	813.9	893.6	1058.9
SEm±		23.4			21.8	
CD5%		66.5			62.0	

S x M interaction that influenced the total soil N in 1983-84 and 1984-85 and has been presented in Table 22c shows that with both the methods, S_1 resulted in comparatively higher total soil N during both the years. With M_1 in 1983-84, S_1 and S_2 were at par with each other and recorded significantly higher total soil N compared to S_3 but with the same method in 1984-85, each increase in seed rate resulted in a significant decrease in total soil N. With M_2 in 1983-84 the differences in total soil N due to seed rates were not significant, but in 1984-85 the two higher seed rates (S_2 and S_3) while remaining at par with each other recorded significantly lower total soil N when compared with S_1.

Table 22c. Effect of S x M interaction on total soil N after harvest (1983-84 and 1984-85)

Seed rates	1983-84		1984-85	
	M_1	M_2	M_1	M_2
S_1	982.9	1064.1	1037.1	1104.0
S_2	961.2	1058.1	965.1	1050.0
S_3	814.4	1053.2	851.0	1047.9
SEm±	15.4		16.7	
CD5%	43.9		47.4	

At each seed rate during both the years, the surface method of FYM application (M_2) recorded significantly higher total soil N.

4.6.7. Soil organic carbon (%)

The organic carbon data also contained in Table 22 reveal that seed rates did not influence the organic carbon content significantly whereas each increase in the rate of FYM application registered a significant increase in 1982-83 and 1984-85. In 1983-84 though 5 and 10 t/ha FYM rates were at par with each other but both of them differed significantly from 15 t/ha.

In respect of methods of application of FYM in the year 1982-83 there was no significant difference due to two methods but during rest of the two years surface application of FYM recorded higher organic carbon content and differed significantly from the incorporation method.

The first order of interactions, S x F, S x M and F x M influenced the organic carbon content significantly after harvest in 1982-83. Being significant only for single year, the data therefore, have been embodied in Appendix XXI, XXII and XXIV, respectigely.

4.7. Nutrient balance

It is essential to maintain a record of the nutrients applied in the soil, removed by the crops, balance after the crop season and the gains(+) and/ or losses (-) occuring thereby. Such balance sheet would enable use to have a real picture of the dynamics of the plant nutrients to draw out a natural picture of fertility of the soil. The yearwise balance sheet of N, P and K has been presented in Tables 23, 24 and 25, respectively. Since the data were not analysed statistically, therefore, only a generalization has been made about this study.

4.7.1. Nitrogen balance

Nitrogen balance data presented in Table 23 show that during all the 3 crop seasons a negative (-) balance of N was observed under all the treatments. It was seen that increase in seed rates decreased the loss of N, while increase in FYM rates, resulted in a decrease in the nitrogen loss. While comparing the method of FYM application, it was found that the minimum loss of N was recorded in surface application of FYM.

Table 23. Balance sheet of soil nitrogen (kg/ha)

Treatments	Available soil N (initial)	N-added during crop season	N-removed by the crop	Balance (3-4)	Calculated available N(balance in soil)	Available soil N after harvest	Net gain(+) or loss(-) of available N
1.	2	3	4	5	6(2+5)	7	8(7-6)
				1982-83			
A. Seed rates (kg/ha)							
100	418.00	100.00	51.4	48.6	466.6	436.2	-30.4
125	418.00	100.00	63.5	36.5	454.5	435.0	-19.5
150	418.00	100.00	69.7	30.3	448.3	434.6	-13.7
B. FYM rates (t/ha)							
5	418.00	100.00	50.7	49.3	467.3	421.2	-46.1
10	418.00	100.00	63.9	36.1	454.1	432.5	-21.6
15	418.00	100.00	69.4	30.6	448.6	452.2	- 3.6
C. Application methods							
Incorporation	418.00	100.00	58.1	41.9	459.9	429.7	-30.2
Surface applied	418.00	100.00	64.6	35.4	453.4	440.9	-12.5
				1983-84			
A. Seed rates (kg/ha)							
100	378.00	100.00	28.4	71.6	449.6	394.1	-55.5
125	378.00	100.00	32.6	67.4	445.4	401.4	-44.0
150	378.00	100.00	47.5	52.5	430.5	394.0	-36.5
B. FYM rates (t/ha)							
5	378.00	100.00	25.8	74.2	452.2	382.0	-70.2
10	378.00	100.00	33.7	66.3	444.3	398.6	-45.7
15	378.00	100.00	39.0	61.0	439.0	408.9	-30.1
C. Application methods							
Incorporation	378.00	100.00	30.5	69.5	447.5	392.0	-55.5
Surface applied	378.00	100.00	35.0	65.0	443.0	401.0	-42.0
				1984-85			
A. Seed rates (kg/ha)							
100	371.00	100.00	36.0	64.0	435.0	388.9	-46.1
125	371.00	100.00	41.7	58.3	429.3	386.8	-42.5
150	371.00	100.00	67.0	33.0	404.0	377.9	-26.1
B. FYM rates (t/ha)							
5	371.00	100.00	38.8	61.2	432.2	375.7	-56.5
10	371.00	100.00	47.3	52.7	423.5	379.2	-44.3
15	371.00	100.00	58.4	41.6	412.6	398.7	-13.9
C. Application methods							
Incorporation	371.00	100.00	43.0	57.0	428.0	374.4	-53.6
Surface applied	371.00	100.00	53.5	46.5	417.5	394.7	-22.8

4.7.2. Phosphorus balance

Like nitrogen, in case of phosphorus also a negative (-) balance was noticed (Table 24). Only in 1982-83 there was a +ve balance when FYM was applied @ 15 t/ha. However, contrary to N balance it was seen that the loss of phosphorus increased with the increase in seed rate. With the application of FYM there was a decrease in the P loss. In respect of P balance also the surface application of FYM resulted in decreased loss of P.

4.7.3. Potassium balance

The K balance after each crop season has been presented in Table 25. Contrary to N and P balance, it was seen that during all the 3 years, there was a net gain in the K status of soil after each crop season. Each increase in seed rate resulted in an increase in available K after the harvest of the crop. Likewise each increase in FYM application also resulted in corresponding increase in K status of soil. The surface method of FYM application helped in building up increased amount of available K in the soil.

Table 24. Balance sheet of soil phosphorus (kg/ha)

Treatments	Available soil P (initial)	P added during crop season	P removed by the crop	Balance	Calculated available P(balance in soil	Available soil P after harvest	Net gain(+) or loss(-) of available P
1.	2.	3.	4.	5(3-4)	6(2+5)	7.	8.(7-6)
				1982-83			
A. Seed rates(kg/ha)							
100	15.0	13.1	4.3	8.8	23.8	23.7	-0.1
125	15.0	13.1	5.1	8.0	23.0	21.2	-1.8
150	15.0	13.1	5.7	7.4	22.4	20.5	-1.9
B. FYM rates (t/ha)							
5	15.0	13.1	4.2	8.9	23.9	19.2	-4.7
10	15.0	13.1	5.1	8.0	23.0	21.7	-1.3
15	15.0	13.1	5.7	7.4	22.4	24.6	+2.2
C. Application methods							
Incorporation	15.0	13.1	4.7	8.4	23.4	21.0	-2.4
Surface applied	15.0	13.1	5.3	7.8	22.8	22.7	-0.1
				1983-84			
A. Seed rates (kg/ha)							
100	12.0	13.1	3.0	10.1	22.1	21.8	-0.3
125	12.0	13.1	3.8	9.3	21.3	20.0	-1.3
150	12.0	13.1	4.2	8.9	20.9	19.1	-1.8
B. FYM rates (t/ha)							
5	12.0	13.1	3.0	10.1	22.1	17.6	-4.5
10	12.0	13.1	3.6	9.5	21.5	21.1	-0.4
15	12.0	13.1	4.3	8.8	20.8	22.5	-1.7
C. Application methods							
Incorporation	12.0	13.1	3.4	9.7	21.7	19.3	-2.4
Surface applied	12.0	13.1	3.9	9.2	21.2	21.3	+0.1
				1984-85			
A. Seed rates (kg/ha)							
100	11.0	13.1	3.7	9.4	20.4	17.3	-3.1
125	11.0	13.1	4.5	8.6	19.6	17.0	-2.6
150	11.0	13.1	5.0	8.1	19.1	16.3	-2.8
B. FYM rates (t/ha)							
5	11.0	13.1	4.1	9.0	20.0	16.4	-3.6
10	11.0	13.1	4.4	8.7	19.7	17.2	-2.5
15	11.0	13.1	4.8	8.3	19.3	17.0	-2.3
C. Application methods							
Incorporation	11.0	13.1	4.1	9.0	20.0	16.9	-3.1
Surface applied	11.0	13.1	4.7	8.4	19.4	16.8	-2.6

Table 25. Balance sheet of soil potassium (kg/ha)

Treatments	Available soil K (initial)	K added during crop season	K removed by the crop	Balance	Calculated available K balance in soil	Available soil K after harvest	Net gain(+) or loss(-) of available K
1.	2.	3.	4.	5.(3-4)	6.(2+5)	7.	8(7-6)
				1982-83			
A. Seed rates (kg/ha)							
100	201.0	25.0	58.9	-33.9	167.1	208.5	44.4
125	201.0	25.0	72.2	-47.2	153.8	207.7	53.9
150	201.0	25.0	86.1	-61.1	139.9	202.8	62.9
B. FYM rates (t/ha)							
5	201.0	25.0	61.8	-36.8	164.2	201.5	37.3
10	201.0	25.0	71.4	-46.4	154.6	202.2	47.6
15	201.0	25.0	84.0	-59.0	142.0	215.3	73.3
C. Application methods							
Incorporation	201.0	25.0	68.6	-43.6	157.4	199.7	42.3
Surface applied	201.0	25.0	76.2	-51.2	149.8	213.0	63.2
				1983-84			
A. Seed rates (kg/ha)							
+100	190.0	25.0	35.5	-10.5	179.5	201.2	21.7
125	190.0	25.0	43.8	-18.8	171.2	200.5	29.3
150	190.0	25.0	52.3	-27.3	162.7	196.4	33.7
B. FYM rates (t/ha)							
5	190.0	25.0	34.1	- 9.1	180.9	192.4	11.5
10	190.0	25.0	43.7	-18.7	171.3	197.1	25.8
15	190.0	25.0	53.8	-28.8	161.2	208.5	47.3
C. Application methods							
Incorporation	190.0	25.0	40.1	-15.1	174.9	194.6	19.7
Surface applied	190.0	25.0	47.7	-22.7	167.3	204.1	36.8
				1984-85			
A. Seed rates (kg/ha)							
100	203.0	25.0	45.1	-20.1	182.9	214.2	31.3
125	203.0	25.0	54.7	-29.7	173.3	213.2	39.9
150	203.0	25.0	83.1	-58.1	144.9	204.0	59.1
B. FYM rates (t/ha)							
5	203.0	25.0	46.1	-21.1	181.9	205.0	23.1
10	203.0	25.0	59.6	-34.6	168.4	206.9	38.5
15	203.0	25.0	77.1	-52.1	150.9	219.5	68.6
C. Application methods							
Incorporation	203.0	25.0	55.3	-30.3	172.7	209.2	36.5
Surface applied	203.0	25.0	66.7	-41.7	161.3	211.7	50.4

5. DISCUSSION

The experimental results emanating from the current investigation, "Studies on the effect of rates and methods of FYM application and seed rates on late sown rainfed wheat (Triticum aestivum L.)" comprising varying seed and FYM rates and methods of FYM application have been presented in the preceding chapter. An attempt has been made in this chapter to interpret the observed effects in the light of available evidences and to establish a cause and effect relationship.

5.1. General

Late sown wheat was grown in the year 1982-83, 1983-84 and 1984-85 on a soil medium in N, P and K. The experimental fields were well drained and uniform in soil fertility.

Weather conditions, particularly under rainfed farming play a great role in the success of farming. At Palampur, winters are cold with a mean minimum temperature in January varying from 2.6°C to 4.2°C. Occasional frosts also occur during late December or early January. Ground temperature sometimes touches 0°C. The low temperature hampers the normal germination and growth of the crops sown late in December or early January. Seeds imbibe water for germination when sown in the soil but due to the low soil temperature this process is generally slowed down delaying the germination. This delay in germination or retarded growth rate of the young seedlings due to low temperature further enhances the duration of its maturity affecting the grain production adversely.

The meteorological data presented in Appendix I for the period of investigation show that the crop season in 1982-83 was more favourable for crop production than that in 1983-84 and 1984-85. The rainfall during the latter two crop seasons was not adequate and distributed evenly, which may be termed as unfavourable for wheat growth. The differences had their impact on yield which is evident from the yield (Table 12) showing considerably higher grain yield in 1982-83 as compared to the latter two years. The effects of different treatments during this study are discussed under following heads.

5.1.1. Effect of seed rates

5.1.2. Emergence and growth studies

The data presented in Table 5 revealed that the seed rates had not influenced the days taken for germination in 1984-85 but in 1982-83 and 1983-84 it was seen that as the seed rate increased the number of days taken to germination decreased. The effect of higher seed rate in enhancing the germination may be associated with expected increase in soil temperature due to increased metabolic activities during the process of germination. Comparatively low temperature does reduce the speed of germination (Read and Beaton, 1963).

Two types of observations were made in respect of shoot number per metre running row length (Table 5). Firstly, the number of shoots significantly increased with the increase in seed rate and secondly, the number of shoots increased with the age of the plant upto 10 WAS and then slowly decreased showing the death of late tillers at harvest. Seed rates brought about significant variation in plant population. A lower seed rate (100 kg/ha) displayed less plant density. Increase in seed rate increased the plant density. In conformity with the present findings Randhawa and Jolly (1974) also reported that seed rate has a pronounced effect on number of tillers per metre running length. In fact , the number of plants as well as tillers increase with the increasing seed rate (Bhardwaj et al., 1973). Rathi and Misra (1973), Singh et al. (1975) and Chela and Brar (1975) observed an increase in initial crop stand with the increasing seed rate. The higher initial plant population produced higher number of tillers.

The ear head bearing tillers were also reported to be more with increase in plant density (Holiday, 1960; Suput, 1966, and Roy et al., 1969).

It can, therefore, be summarised that the increase in number of shoots per metre running row length and increase in effective tillers (Table 11) due to increase in seed rate as obtained in the present investigation may have much bearing on final grain yield. Thus, for a cultivar like sonalika which is bold seeded and shy tillering and more so particularly under late dry sown conditions a higher seed rate may be desirable. Mahendra and Sharma (1976) also reported that increasing the seed rate from 75 to 125 kg/ha increased the plant density, but as in present study they also observed decrease in 1000-grain weight and number of grains per spike (Table 11).

The data presented in Table 6 revealed a decrease in plant height with an increase in seed rate indicating that under limited moisture supply, thinner plant density may tend to produce taller plants. Green matter, dry matter production (g/m^2) and per cent dry matter accumulation at various stages of growth during all the 3 years of investigation increased with increase in seed rate (Tables 7, 8 and 9). This may be linked to higher number of shoots obtained at higher seed rate (Table 5). Similar findings on the effect of seed rates on green matter, dry matter and per cent dry matter production have also been reported by Chela and Brar (1975), Randhawa et al.(1977) and Rajat De and Giri (1978).

Like plant height, spike length, spikelets per spike, grains per spike and 1000-grain weight also decreased with the increase in seed rates (Table 11). The present investigation corroborate the findings of Sandhu et al.(1975) who concluded that increased seed rate from 50 to 100 or 150 kg/ha resulted in significant reduction in ear length and grains per ear. However, the lower ear weight at the higher rate of seeding was compensated by higher plant population. In the present study also higher plant population particularly the effective tillers per metre row length might have compensated for this loss.

5.1.3. Yield

The data presented in Table 12 and Fig.6 revealed the significant effect of seed rates on grain as well as on straw yield of wheat during the 3 years and that obtained on pooling the data. The low yield of grain and straw in the year 1983-84 may be attributed to uneven and unsufficient rainfall during the crop season and dry conditions prevailing particularly during early stages stages of crop growth (Fig.1 and Appendix I). The pooled yield data in respect of grain as well as straw (Table 12) revealed a significant increase as the seed rates increased from 100 to 150 kg/ha. The increase in grain and straw yield over 100 kg seed rate/ha was to the extent of 35.9 per cent and 49.0 per cent, respectively. Wheat grain yield has been said to be a function of number of plants/unit area, number of effective tillers/plant, number of grains/ear and weight of individual grain (Arnon, 1975). In the present study the number of plants per unit area measured in terms of number of shoots/metre running row length (Table 5) and fertile tillers/ plant measured in term of effective tillers per metre row length (Table 11) invariably increased with increase in seed rate upto 150 kg/ha. However, this was not accompanied by a similar increase in number of grains/ear expressed as grains/spike and weight of individual grain measured in terms of 1000-grain weight (Table 11). There appeared to exist a -ve correlation between tiller number and grains/spike and tiller number and 1000-grain weight with the increase in seed rates. Such relationship has been reported by many workers (Gupta et al. 1968; Mehta and Mathur, 1972; and Singh et al., 1975).

It may, therefore, be inferred that in the present study the plant population and the effective tiller number helped in getting more grain yield at higher seed rates. Similar type of observations have been made by Bhardwaj and Whight (1967), Singh et al.(1971), Vez (1972), Bishnoi and Gill (1972), Bains and Bhardwaj (1972), Sumbali and Sharma (1973), Dhiman and Kalra (1978); Shukla and Misra (1979), Rana (1980) and Kalita and Chaudhari (1984).

5.1.4. Nutrient concentration and uptake

Almost at all the stages the N content in the plants was more at higher seed rate during all the 3 years (Table 13). There does not appear to be direct relationship between seed rate and plant nitrogen content which might have resulted in these types of results but since nitrogen was not a limiting factor in the present study and it was applied uniformly at the rate of 100 kg/ha, therefore, higher plant density obtained at higher seed rate might have utilized the available nitrogen efficiently. However, due to the lack of published reports on this type of behaviour of seed rates, it may still remain a point of controversy.

The protein content of grains obtained during the course of this study was invariably low (Table 14). This can be attributed to increased straw yield which was obtained during all the 3 years of experimentation resulting in a very low harvest index. The nitrogen might not have been able to translocate to the sink i.e. grains, ultimately resulting in low concentration of nitrogen in grains (Table 13) and therefore, the protein. However, higher seed rate resulted in higher protein content in grains (Table 14). This may be attributed to the significant increase in N content in grains due to an increase in seed rates. Similar results have also been reported by Singh (1963), Mahapatra and Leelavathi (1971), Waldran and Flowerday (1979) and Halloran and Lee (1979).

In conformity to the present findings, Kiesselback (1926) also reported that crop quality has a positive correlation to seeding practices.

Nitrogen uptake is a function of nitrogen content in plant and the dry matter production. The higher uptake at higher seed rate can therefore, be attributed either to the higher nitrogen content (Table 13) or to the high dry matter production (Table 8) or to both at the respective stages of growth. The highest uptake at 18 WAS or at harvest also be attributed to the same reasons. Similarly, the higher protein yield at higher seed rate (Table 14) can also be attributed to higher grain yield and higher protein content obtained at these seed rates. These results are in conformity with those obtained by Smika and Ellis (1971), Agarwal (1974), Mahapatra and Leelavathi (1971) who have also reported that higher seed rate was conducive to higher nitrogen uptake.

P content in plants was higher at higher seed rates (Table 16). Also the P content was higher at early stages of crop growth and decreased subsequently at 18 WAS. By this time it appears that the nutrient got translocated towards ear head. Subsequently at harvest when the grains and straw were analysed separately it was confirmed that the nutrient had got translocated to the grains resulting in higher P content in grains and in very low concentration in straw. These findings suggest that higher seed rate not only resulted in higher grain yield but also resulted in grain of higher quality. Similar type of observations have been made by Boatwright &Haas (1961) [illegible].

It was interesting to note that higher seed rate resulted in higher P uptake and it increased with the age of the plant and was maximum at harvest (Table 17). The removal of P from the soil at a constant rate till harvest corroborates the observations of Asana and Sarin (1968) who while working under rainfed conditions claimed that the uptake of P continuousto increase right upto the end. Sharma (1986) also reported that the uptake values by the plants were considerably low. This shows that in the absence of optimum supply of soil moisture, the uptake of phosphorus does not take place at desired level.

Like N and P, K content also increased with the increase in seed rates. Similarly, the uptake of K also increased with the seed rates and the age of plant (Tables 18 and 19). The nutrient uptake studies therefore, suggest that for efficient utilization of plant nutrients, there has to be considerable increase in the seed rates whenever the sowing is delayed. Under normal sown conditions perhaps the higher rate of tillering may compensates for lower seed rate but when sowing is delayed the tillering is normally poor and the differences in tillers/shoot (Table 5) and dry matter (Table 8) persists till the maturity period.

5.2. Effect of FYM

5.2.1. Emergence and growth studies

The soil temperature recorded in 1982-83 and 1984-85 revealed that the increase in FYM rates from 5 to 15 t/ha resulted in an increase in soil temperature from 0.8°C to 1.3°C in 1982-83 and from 0.9°C to 2.0°C in 1984-85. Also, the surface application enhanced the soil temperature from 1.9°C to 2.2°C in 1982-83 and from 2.0°C to 2.4°C in 1984-85 (Table 20). Though these observations were recorded after the germination had almost completed but such type of differences could be expected to exist right from the time of sowing. Also, the higher FYM rates and the surface application resulted in higher soil moisture content whenever the observations were recorded (Table 21). The enhanced soil temperature and the moisture content reflected in the number of days taken for seed germination when. It was observed that whenever FYM was applied at higher rate it took lesser number of days to complete the germination. Also, the surface application of FYM resulted in lesser number of days to complete germination (Table 5). Such increase in soil temperature and thereby enhancement in the germination by the use of FYM as mulch (Spreading on the soil surface) has also been reported by Bains et al.(1968), Dayanand (1971), Patil and Bhardwaj (1976), Rao and Bhardwaj (1983) and Acharya and Bhagat (1986). Also, an increase in soil moisture content by corresponding increase in FYM rates or by the surface application of FYM can also be expected either by the improvement of soil physical properties such as decrease in bulk density or increase in organic carbon or by the mulch effect (Table 22). Similar observations have also been made by Dharmade and Biswas (1968); Biswas *et al.* (1971); Khanna *et al.*(1975); Gattani *et al.*(1976), Prasad and Singh (1980) and Bhatia and Shukla (1982).

The plant height and number of shoots per metre row length were higher at higher FYM rate and also where FYM was applied on the surface (Tables 5 and 6). Comparatively favourable soil temperature and soil moisture at higher FYM rates or due to its surface application (Table 5) can be held responsible for higher plant density almost at each stage of crop growth. Taller plants and higher plant density were also responsible for more fresh and dry matter accumulation in the plant (Table 5, 6 and 7) due to these treatments. The importance of FYM in increasing plant growth through its effect on soil temperature or by improving the physical condition of soil has been emphasized by many workers. Bains *et al.* (1968) reported that the initial root development is badly slowed down due to low soil temperature. Bower (1970) reported that root development gets doubled when the soil temperature is raised from 15°C to 25°C. Similar findings have been reported by Cary (1969). Not only for soil temperature but FYM has also been considered a source of almost all the essential plant nutrients and the association with micro-organisms, it helps in synthesis of certain phytohormones and vitamins which promote the growth and development of the crop (Raychaudhuri, 1977). The organic manures are also known to increase the cation exchange capacity of soil, forming chelates with metal micro nutrients elements consequently the leaching losses are considerably reduced (Khanna and Stevenson, 1962). Besides these beneficial effects, FYM also helps in improving the soil structure which, in turn, increase the infiltration and retention of water, improves soil aeration and root penetration and increases the microbial population (Baver, 1972; Biswas et al.,1969 and Prasad et al.,1982).

The increase in FYM rates was found to result in lesser number of days taken to 50 per cent and 100 per cent heading and to maturity (Table 10). Contrary to this the surface application of FYM was found a result in comparatively more number of days to 50 to 100 per cent heading as well as to maturity. This might be the effect of FYM mulch, that retained more moisture in the soil for longer period.

5.2.2. Yield

The beneficial effect of higher FYM rates and surface application on growth, development and yield contributing characters was duly reflected in final grain and straw yield, where during each year as well as in pooled analysis it was seen that higher FYM rates and surface application resulted in higher grain and straw yield (Table 12). While discussing the effect of seed rates it was stated that yield was mainly a function of plant population and number of effective tillers per unit area but here it can be seen that higher number of tillers, spike length, spikelets per spike, grains per spike as well as 1000-grain weight (Table 11) contributed towards the final yield. Though 1000-grain weight is the character which is affected least by environmental changes but the favourable soil moisture conditions prevailing during the crop growth period at higher FYM rates and FYM applied on the soil surface seems to be have resulted in bolder grains. Higher grain yield of wheat at higher FYM rates has been reported by many workers (Sharma, 1983 and Ganai, 1983). Gupta (1985) also concluded that FYM application @ 8 t/ha in late sown wheat caused a significant increase in the yield of wheat over control. Similarly, the surface application of FYM has also been reported by Patil and Bhardwaj (1976), Dayanand et al. (1977) and Ram and Bhardwaj (1983) to result in higher grain and straw yield of wheat crop.

Almost all the yield contributing characters namely number of effective tillers per metre running row length, spike length, spikelets per spike, grains per spike and 1000-grain weight increased with the increase in FYM rates. The surface application of FYM also had a similar effect when compared with incorporation. The presence of FYM in the soil at higher rates or when it was applied on the soil surface provided so favourable conditions for the growth and development of the plants that a negative relationship that existed between tiller number and spikelets per spike and grains per spike and 1000-grain weight at higher seed rates seemed to have been offset (Table 11). These findings are in agreement with the results of Stickler(1962), Sandhu et al.(1975),Mahendra and Sharma (1976) and Borse and Mahajan (1984). Some of the favourable conditions at higher FYM rates as well as by surface application have been observed in the present study also when almost at all the stages a higher soil moisture content was observed at higher FYM rates and when FYM was applied on the surface (Table 21). Also, bulk density, available soil N, P and K and organic carbon was higher at higher rates and when FYM was applied on the soil surface (Table 22). Some beneficial effects of FYM on these yield contributing characters have also been reported by Attia (1970), Sachan (1976), Rajat De and Giri (1978) and Ram and Bhardwaj (1983).

As stated earlier the straw yield of wheat increased significantly with the application of FYM (Table 12). The straw yield of crop is the resultant product of number of shoots per unit area and plant height. It is apparent from Fig.3 and 4 that these parameters of wheat were considerably higher at higher rate of FYM as well as when FYM was applied on the soil surface.

Application of FYM in general did not bring about significant changes in harvest index of wheat (Table 12). However, in 1984-85 the harvest index of wheat was significantly higher due to surface application of lower rate of FYM. Harvest index is used to assess the efficiency of a crop to produce grains or more especially it indicates the relationship between the source and sink. Any factor that has preferential effect on any one of them or when any environmental or nutritional factors are limited either during development, anthesis or grain filling period of crop growth would bring about changes in source and sink relationship and ultimately on the harvest index.

In case of pooled analysis also the FYM application could not bring the change in harvest index. The photosynthetic activity of the ear, which is situated at the top of the stalk makes a considerable contribution to grain formation(Rawson et.al 1976). Particularly all the dry matter of grain is produced by part of the shoot above the flag leaf node. Of this dry matter, the ear contributes about 50 per cent in wheat (Asana and Mani, 1949). But low rainfall in 1983-84 which caused a considerable decrease in the yield of total dry matter must have decreased the harvest index. Bunting and Drennan (1966) also reported that due to decrease in dry matter and yield of wheat harvest index also decreased.

5.2.3. Nutrient concentration and uptake

The increase in FYM rates resulted in corresponding increase in N, P and K content in plants. Similarly, the surface application of FYM also resulted in an increase in the per cent content of these nutrient elements in plants (Tables 13, 16 and 18). This may be explained partly due to enrichment of the soil at higher FYM rates and partly due to better temperature, moisture and physical conditions of the soil resulting in better root and shoot development. Higher uptake of these nutrient elements almost at each growth stage at higher FYM rates and surface application of FYM(Tables 15, 17 and 19) was the direct effect of their higher concentration (Tables 13, 16 and 18) and better shoot growth measured in terms of shoot number and plant height (Tables 5 and 6) resulting in higher dry matter accumulation (Table 8). Similar to the present findings Olsen et al.(1970), Mann et al.(1973) and Boon and Venter (1976) also reported significant increase in N content of leaves, ear and stem of wheat with the application of organic matter. Datta and Srivastava(1963), Whitehead (1963), [illegible]; Olsen et al.(1970) and Houque and Sotakora (1978) also reported higher uptake of N, P and K with the application of FYM.

The protein yield which is a product of N content in grains and the grain yield was duly reflected in the protein yield where it was seen that more crude protein yield was obtained at high FYM rates and when FYM was applied on the surface. In 1982-83, the increase was even significant (Table 14). In conformity with the present findings Dayanand et al. (1972) Ram Sewa(1975) and Patil and Bhardwaj (1976) also reported an increase in protein yield with the application of FYM.

The mechanism believed in increasing the phosphorus uptake was also explained by Drake and Steckel (1955) who suggested that higher phosphorus uptake in the presence of FYM may be due to the reduction of Ca activity in soil solution via the bonding of Ca by the plant root exchange sites, thereby resulting in increased phosphorus uptake and reduction of Fe and Al activity in soil solution via the complexing of these cations by root exuded organic anions. Such a role of FYM is also understandable from its property of mobilizing both native and applied phosphorus thus reflecting its effect on the uptake of phosphorus and other nutrients.

5.2.4. Physico-chemical properties of soil and nutrient availability

The acidifying effect of FYM at higher rates was reflected in lower pH (Table 22). Also, the surface application lowered the pH but the effect was not as conspicuous as that of increased rate of FYM. There are reports where soil pH has been found to be affected in different ways depending upon the type of soil and the amount of FYM applied. Kanwar and Prihar (1962b) and Singh et al. (1980) reported a decrease in soil pH in the presence of FYM which may be explained in view of the fact that during the decomposition of FYM in the soil several organic acids are released which might cause depression of soil pH.

Results on bulk density (Table 22) revealed that it was significantly lowered with the increase in FYM rates and also when it was applied on the soil surface. Similarly, the organic carbon content after the harvest was also higher whenever FYM was applied at higher rates as well as when FYM was applied on the soil surface. It was not infrequent that soil bulk density has been used to judge the porosity or soil aggregation. A well aggregated soil has lower bulk density compared with a dispersed and poorly structured soil. Bhardwaj and Patil (1982) pointed out that a close relationship existed between the soil organic matter content, microbial population and soil aggregation. The organic carbon content and microbial population of soil were increased due to the application of FYM. The soil organic matter being acted upon by the micro-organisms might have resulted in considerable increase in polysaccherides and microbial gum synthesis in the soil. These microbial decomposition products being resistant to further decomposition have been reported to act as soil particle binding agents (Dhoot et al., 1974). This might help in soil aggregation resulting in a low bulk density of soil. Similar type of observations have been made by a number of workers elsewhere also (Biswas et al., 1971; [illegible]; Prasad and Singh, 1980; Bhatia and Shukla, 1982 and Gupta et al., 1983).

It was also apparent from the present study that the available nitrogen, phosphorus and potassium after the harvest of the crop invariably increased with the increased rates of FYM and with the surface application of FYM (Table 22). Since the FYM which was applied in 1982-83 had 0.59, 0.18 and 0.60 per cent, in 1983-84 0.50, 0.16 and 0.47 per cent and in 1984-85, 0.53, 0.19 and 0.56 per cent N, P_2O_5 and K_2O, respectively, its addition is likely to improve the content of these nutrients in the soil. Also, it has been estimated that from the applied FYM less than 30 per cent of nitrogen, above 60-70 per cent phosphorus and above 75 per cent of potassium generally become available to the immediate crop and rest of the plant nutrients become available to the subsequent crop (Gaur et al., 1984). The increase in the available N content due to favourable effect of FYM on physico-biological properties of soil has been demonstrated which might have improved the microbial population as well as their activity which were responsible for mineralization of organic N compounds (Kanwar and Prihar, 1962; Mandal and Jain, 1965; Gill and Meelu, 1980 and Kapur et al., 1981)

The accumulation of phosphorus due to FYM application can partly be explained on the basis of the fact that organic acids produced during its decomposition may be involved in the replacement of phosphorus from the sesquioxides in soil (Sinha, 1970 and Bhardwaj and Patil, 1982). Bhardwaj et al. (1982) have attributed increased supply of K from the FYM itself due to mineralization and release of K from K bearing minerals from the solvent action of organic acids produced during decomposition of FYM.

In the light of facts explained above it was not uncommon to obtain higher quantities of available N, P and K at higher rates of FYM and also when it was applied on the soil surface. The significant effect may not be reflected always.

The total N includes both organic and inorganic forms of N in soil. Some of NH_4^+ ions are absorbed on the clay complex which reflects its effect in the form of residual value (Black, 1965). It may become slowly available after its mineralization. The data in Table 22 revealed that FYM at higher rates as well as when it was applied on the soil surface significantly increased the total N status of soil during all the 3 years of experimentation. The higher rates of FYM resulting in higher nutrient status (available as well as total) may be questionable. But it is just possible that the low temperatures (soil as well as atmospheric) that prevailed during the winter months might have not encouraged the losses due to denitrification from the soil surface. The influence of organic manures in increasing the total N content of the soil has been observed in several long term field experiments (Sen and Bande, 1962; Kanwar and Prihar, 1962, Chaudhary and Vocchani, 1965; and Kapur et al., 1981). Gill and Meelu (1980) indicated that continuous use of organic manures increased the total N when compared with organic fertilizers.

5.2.5. Effect of interactions

The grain yield of wheat in 1982-83 and 1983-84 was significantly influenced by the interaction between seed rates and FYM rates (S x F). It has been seen that the highest grain yield was obtained when the combined use of 150 kg seed rate alongwith application of FYM at the rate of 15 t/ha was made. Similar type of effect was also noted for green matter accumulation at 6 WAS during all the 3 crop seasons (Table 7.1a) and dry matter accumulation at 14 WAS in 1982-83 and 1983-84 (Table 8.1b). The superiority of this treatment combination was also consistent in respect of other yield contributing characters such as number of effective tillers during all the 3 years (Table 11.1a) and in the pooled data for 3 years regarding other characters viz., Spikelets per spike (Table 11.1c), number of grains per spike (Table 11.1d), 1000-grain weight (Table 11.1f).

In 1982-83, higher moisture content was observed at different growth stages due to S_3F_3 resulted in the higher grain yield (Table 22a). The higher grain yield could be expected due to better soil moisture condition. But in 1983-84 it was a drought year, therefore, the yields were very low, but higher rate of FYM application conserved the more moisture in the soil as compared to control (5 t/ha).

All these yield contributory characters might have interacted in a manner that the effect was manifested to a significant level in the grain yield of wheat. More or less similar type of observations have been made by Mahrotra and Agnihotri (1970), Sharma et al.(1971), Agarwal et al.(1971) and Singh et al. (1971). They observed that the yield increased linearly with the increase in seeding rates and in nitrogen rates under late sown conditions of wheat, though the nitrogen application was not a treatment in the present study but more nitrogen can be expected to be available at higher levels of FYM which in addition to its effect on soil physical properties can result in higher yields.

The protein content of the grains was influenced significantly by seed rates x FYM rates in 1982-83 and 1983-84 as well as in pooled analysis (Table 14a). It was seen that increase in rates of seed and FYM resulted in an increase in protein content. It has been seen that S x F interaction at 6 WAS in 1982-83 (Table 13a), at 10 WAS during all the 3 years (Table 13b) and at 18 WAS in 1982-83 and 1983-84 (Table 13c) influenced the N content in plants significantly. This can be corroborated that higher the quantity of FYM, more will be the amount of N supplied to the soil. At the same time because of its slow reaction, the nitrogen supplied through FYM may remain available to the plants for a longer duration during the entire plant growth. Hence the protein content was more at higher rates of seed and FYM.

5.3. Balance of nutrients

The balance sheet of nitrogen (Table 23) showed a deficit balance in all the treatments during the 3 years of experimentation. From a long term experiment a similar type of a negative balance has also been reported by Yaduvanshi et al. (1984). One of the possible reasons for the negative balance can be very less proportion of the added nitrogen removed by the crop plants under rainfed conditions. Secondly, microbial activities are necessary for enhancing nitrogen fixation (Kemmler, 1986). Under the rainfed conditions microbial population cannot be expected to be at optimum level consequently contributing to a net loss of nitrogen.

Available soil P (Table 12) also had a negative balance under all the treatments during the 3 years of experimentation. Only in 1982-83, FYM applied at the rate of 15 t/ha had a positive balance. This can be attributed directly to only a minute fraction taken by the crop plants. So far as the available soil P status before the sowing of the crop and after the harvest of the crop is concerned there was not much difference at least in 1983-84 and 1984-85. This clearly indicated that most of the applied P got fixed and resulted in a negative balance.

Contrary to nitrogen and phosphorus there was a positive balance of available potassium (Table 25) under all the treatments during all the 3 years of experimentation. In 1982-83 and 1984-85 which were not as severe in respect of drought occurrence in comparison to 1983-84, K removed by the crop plant was in excess of the added amounts of K. This can be attributed to the removal of K from the soil reserves. Similar type of observations have also been made by Yaduvanshi et al. (1984). These observations also indicate that there is good reserve of potassium in the soil.

6. SUMMARY

The current investigation entitled "Studies on the effect of rates and methods of FYM application and seed rates on late sown rainfed wheat (*Triticum aestivum* L.)" was undertaken with the following objectives:

1. To assess the optimum seed and farm yard manure rates for late sown rainfed wheat under mid-hill conditions of Himachal Pradesh,
2. to find out suitable method of FYM application for higher yields,
3. to study the effect of FYM application on the physico-chemical properties of soil,
4. to assess the nutrient status in respect of N, P and K under different FYM treatments, and
5. to observe the interaction effect among seed rates, FYM levels and methods of FYM application, if any.

In order to meet the objectives of the said investigation a field experiment was initiated at the Research Farm of Department of Agronomy and Agrometeorology, Himachal Pradesh Krishi Vishva Vidyalaya, Palampur, District Kangra, situated at 32°6'N latitude and 76°3' E longitude about 1290 metres above m.s.l. with sub-temperate type of climate, during the Rabi season in the year 1982-83, 1983-84 and 1984-85. The experiment consisting of eighteen treatment combinations of three seed rates (100, 125 and 150 kg/ha), three farm yard manure rates (5, 10 and 15 t/ha) and two methods of FYM application (incorporation of FYM in soil and surface application) was laid out in 3^2x2 factorial partially confounded design, replicated four times. Wheat (S-308) was taken as a test crop. The soil on which the experiment was conducted had a clay loam texture with 418, 15 and 201 kg of available N, P and K, respectively in 1982-83, 378, 12 and 190 kg of available N, P and K in 1983-84 and 371, 11 and 203 kg of available N, P and K in 1984-85. The soil pH during all the 3 years was 5.5.

The entire amount of P (superphosphate 16% P_2O_5) and K (muriate of potash 60% K_2O) and 2/3 of N (urea 46% N) were banded 3-5 cm below the seed at the time of sowing of crop. The remaining N was supplied after 2 months. All the plots received a uniform dose of 100 kg N, 30 kg each of P_2O_5 and K_2O per hectare. The main findings that emerged from the present investigation are summarised as under:

6.1. Germination and growth

a). Days taken to germination

In 1982-83 and 1983-84 higher seed rate hastened the germination. In 1984-85, however, the influence was not significant.

FYM application at the rate of 15 t/ha also hastened the germination by 2 to 3 days compared to 5 or 10 t/ha. Surface application of FYM resulted in an early germination.

b)Growth characters

(1) Number of shoots: The number of shoots per metre running row length increased with the increase in seed rate and with the age of plant. The shoot number increased upto 10 WAS. At 10 WAS during all the 3 years of experimentation, 150 kg seed rate/ha recorded the highest number of shoots and the increase in shoot number was 21.5, 9.0 and 6.0 per cent over 100 kg/ha in 1982-83, 1983-84 and 1984-85, respectively. In case of FYM rates, 15 t/ha FYM recorded the highest number of shoots at 10 WAS in all the 3 crop seasons. The surface application of FYM proved to be superior to incorporation of FYM in the soil.

(2) Plant height: Plant height decreased by each increase in seed rate upto 150 kg/ha. However, at each seed rate with the increase in age, the height increased progressively upto harvest. On the contrary increase in FYM rates increased the plant height significantly by each increase in FYM rates during

all the 3 years of study. At harvest, in 1982-83, each seed rate differed significantly and maximum plant height was observed at 15 t/ha and increase in plant height was 7 per cent over 5 t/ha. However, in 1983-84 and 1984-85, the increase over 5 t/ha plant height was only 4.0 and 7.0 per cent, respectively. Surface application of FYM increased the plant height significantly and resulted in 4.6, 4.2 and 5.6 per cent increase over the incorporation method in first, second and third year, respectively.

(3) Green and dry matter production: In general, the maximum green and dry matter production was observed at 18 WAS. In 1982-83 and 1983-84 increase in seed rate increased the green and dry matter production and each seed rate differed significantly. In 1984-85, the increase was found only upto 125 kg seed rate/ha. FYM rates contributed to increase the green and dry matter production which was significantly higher at 18 WAS and both these parameters decreased at harvest. At 18 WAS, in 1982-83 and 1983-84, increase in FYM rates increased the green and dry matter production, However, in 1984-85, both these parameters did not differ significantly. Surface application of FYM recorded higher green and dry matter production at 18 WAS in all the 3 years, which differed significantly from incorporation method.

(4) Per cent dry matter production: Per cent dry matter increased with the age upto harvest stage. There was a steep rise in the per cent dry matter production after 10 WAS to harvest stage during all the 3 crop seasons. 150 kg/ha seed rate recorded highest per cent dry matter and each seed rate differed significantly with one another. 15 t/ha FYM resulted in significantly higher per cent dry matter production as compared to 5 t/ha. However, at 6 WAS in 1983-84 and 1984-85 the differences were not significant. Surface method of

FYM application significantly accumulated higher per cent dry matter and differed significantly from the incorporation method.

6.2. Development stages of wheat

i) 50 per cent heading: Increase in seed rates resulted in an increase in number of days taken to 50 per cent heading. In 1982-83, each increase in seed rate resulted in corresponding significant increase in the days taken to 50 per cent heading. In 1983-84 the significant difference was found only between 150 and 100 kg seed rate/ha. In 1984-85, however, the differences were not found to be significant.

In 1982-83, FYM levels did not influence the number of days taken to 50 per cent heading. In 1983-84, 15 t/ha of FYM helped in producing early ear emergence as compared to 5 and 10 t/ha. In 1984-85, application of 15 t/ha took 4 days lesser to 50 per cent heading and each FYM rate differed significantly. Incorporation of FYM in soil also helped in inducing early 50 per cent heading in 1982-83 and 1984-85 but in 1983-84 the differences were not significant.

(ii) 100 per cent heading: Seed rates influenced the 100 per cent heading in 1982-83 and 1984-85. 150 kg/ha seed rate delayed 100 per cent heading by 1 to 2 days. In 1983-84 the difference was not significant. 15 t/ha FYM hastened the completion of heading by 2 to 3 days as compared to 5 or 10 t/ha in 1983-84 and 1984-85. In 1982-83 the FYM rates did not differ significantly. In 1982-83, the methods of application of FYM did not influence the days taken for 100 per cent heading. However, during rest of the two years surface application of FYM took 2 days more to complete the heading.

(iii) Maturity: 150 kg/ha seed rate took about 2 to 3 days more to complete maturity. In 1982-83, each seed rate differed significantly but in 1983-84 and 1984-85, 150 kg/ha seed rate recorded higher number of days to complete maturity and differed significantly from 100 or 125 kg/ha. The latter two seed rates, however, did not differ significantly.

Contrary to this, application of FYM @ 15 t/ha took 3 to 4 days lesser to complete maturity. In 1982-83 and 1983-84 each FYM rate differed significantly However, in 1984-85, 15 t/ha FYM took lesser number of days to complete maturity and differed significantly when compared to 5 or 10 t/ha. Surface application of FYM took 2 to 3 days more to complete the maturity and differed significantly to incorporation of FYM into the soil.

6.3. Yield and yield attributes

(i) Yield attributes

Among the yield contributory characters in 1982-83 and 1984-85, the number of effective tillers increased by increasing the seed rate to 125 kg/ha. In 1983-84, the effective tillers increased by increasing the seed rate upto 150 kg/ha and each seed rate differed significantly. In 1982-83, 15 t/ha FYM significantly increased the effective number of tillers but 5 and 10 t/ha levels remained at par with each other. In 1983-84 the increase in effective number of tillers was observed only upto 10 t/ha. In 1984-85 however, the FYM rates did not differ significantly. Surface application of FYM significantly increased the effective number of tillers and proved to be superior to incorporation of FYM in the soil in all the 3 years of experimentation.

The other yield contributory characters such as spike length, spikelets/spike, grains/spike and 1000-grain weight when pooled for 3 years, significantly decreased by increasing the seed rate to 150 kg/ha. On the contrary, increase in FYM rate to 15 t/ha increased the spike length, spikelets/spike, grains/spike and the 1000-grain weight. In case of surface application of FYM all these yield contributory characters significantly increased as compared to incorporation of FYM in the soil.

(ii) Yield

In case of pooled analysis it was observed that each increase in seed rate increased the grain and straw yield and each seed rate differed significantly. 150 kg/ha seed rate increased the grain and straw yield by 35.9 and 49.0 per cent, respectively over 100 kg/ha. When seed rate was increased from 125 to 150 kg/ha the increase in grain and straw yield was 18.3 and 24.8 per cent, respectively. 15 t/ha FYM increased the grain and straw yield respectively by 31.8 and 33.7 per cent over 5 t/ha and this increase was significant. Increase in FYM rate from 10 to 15 t/ha resulted in 10.7 and 8.5 per cent increase in grain and straw yield, respectively and the increase was significant. Surface application of FYM also recorded significantly higher grain and straw yield.

(iii) Harvest index

In the pooled analysis of 3 years it was seen that 100 and 125 kg seed rate remained at par and recorded significantly higher harvest index as compared to 150 kg seed rate/ha. FYM rates as well as method of application did not influence the harvest index significantly.

6.4. Effect on nutrient concentration and uptake

(i) Nitrogen content (%)

In general, the nitrogen content in plants was higher at 6 WAS and fell progressively as the crop advanced towards maturity in all the 3 years of study, 150 kg/ha seed rate resulted in higher N content in plants and differed significantly from 100 kg seed rate/ha at all the stages.

Increase in FYM rates increased the N content and 15 t/ha differed significantly from 5 t/ha. Higher N content was observed in case of surface application of FYM and differed significantly from the incorporation of FYM in the soil.

(ii) Protein content

Seed rates influenced the protein content in grain significantly during all the 3 years as well as in the pooled analysis. It was seen in the pooled analysis that each increase in seed rate from 100 to 150 kg/ha resulted in significant increase in protein content. In respect of FYM rates in 1982-83, 1983-84 and pooled analyses the highest protein content was at 15 t/ha and each FYM rate differed significantly. In 1984-85 also, the highest protein content was registered at 15 t/ha of FYM and differed significantly from 5 and 10 t/ha, but the latter two FYM rates remained at par with each other. Surface application of FYM recorded the highest protein content and proved significantly superior to incorporation of FYM in the soil in all the 3 years as well as in pooled analysis.

(iii) Protein production (kg/ha)

In 1982-83, seed rates did not differ significantly. In 1983-84, the protein production increased upto 125 kg seed rate/ha and differed from 100 kg/ha. In 1984-85, the highest protein yield was recorded at 150 kg seed rate/ha and each seed rate differed significantly from one another. In 1982-83, FYM rates did not influence the protein production. In 1983-84 and 1984-85, the highest protein production was registered at 15 t/ha and each FYM rate differed significantly. In 1982-83, the methods of application of FYM did not influence the protein production. In 1983-84 and 1984-85, the surface application of FYM recorded the highest protein production.

(iv) P content (%)

P content in plant decreased with the advancement in growth stages. At harvest, in grains, the P content was more as compared to straw. Increase in seed rate to 150 kg/ha recorded the highest P content and differed significantly from 100 kg seed rate/ha.

In respect of FYM rates, 15 t/ha resulted in higher P content and differed significantly from 5 t/ha. Surface application of FYM also recorded higher P content and differed significantly from its incorporation in the soil.

(v) K content (%)

K content increased with increase in seed rate and 150 kg/ha differed significantly from 100 kg/ha. 15 t/ha FYM recorded the highest K content and each FYM rate differed significantly, except at 6 and 10 WAS in 1983-84 and at 18 WAS in 1984-85 FYM rates did not differ significantly. Surface method of FYM application always resulted in higher K content but the differences were not significant at 6 and 10 WAS in 1983-84 and at 18 WAS in 1982-83 and 1984-85.

(vi) N uptake

150 kg seed rate recorded more N uptake and each seed rate differed significantly from one another. 15 t/ha FYM recorded the highest N uptake and each FYM rate differed significantly. Surface application of FYM recorded higher N uptake which proved to be superior to incorporation of FYM into the soil.

(vii) P uptake

P uptake increased with the age of the plant and it was maximum at harvest. 150 kg seed rate recorded highest P uptake and each seed rate differed significantly at all the stages of crop growth during all the three years of study. In all the 3 crop seasons, the P uptake was highest at 15 t/ha FYM and each FYM rate differed significantly. Surface application of FYM recorded higher uptake of P and differed significantly from incorporation of FYM in the soil.

(viii) K uptake

Like P uptake, the uptake of K also increased with the age of the plant upto harvest in all the 3 years of experimentation. The uptake of K was highest at 150 kg seed rate and each seed rate differed significantly from one another.

The uptake of K was also higher at 15 t/ha FYM and each FYM rate differed significantly. Surface application of FYM also recorded the highest K uptake and proved significantly superior to incorporation of FYM into the soil.

6.5. Soil studies

(i) Temperature

The increase in seed rates, in general, registered to a decline in the soil temperature. The highest temperature was recorded at 100 kg seed rate/ha and the lowest at 150 kg/ha. The decline in soil temperature ranged from 1.3°C to 0.8°C in 1982-83 and from 1.3°C to 1.1°C in 1984-85. Increase in FYM rates registered an increase in soil temperature and the increase ranged from 0.8°C to 1.3°C in 1982-83 and from 0.9°C to 2.0°C in 1984-85. Surface application of FYM tended to enhance the temperature of surface soil. The increase ranged from 1.9°C to 2.2°C in 1982-83 and from 2.0°C to 2.4°C in 1984-85 compared to that when FYM was incorporated in the soil.

(ii) Soil moisture content

During all the 3 crop seasons the moisture content in soil decreased significantly with the increase in seed rates. Except at II and IV observation in 1984-85 and V observation in 1983-84 the seed rates did not influence the moisture content. The FYM rates also influenced the soil moisture content at all the observations in all the 3 years. 15 t/ha FYM recorded the highest moisture content. Surface application of FYM retained more moisture in the soil at different observations in all the 3 years and it was significantly superior to incorporation of FYM in the soil.

6.6. Interaction effect

From seed rates x FYM rates (S x F) interaction that influenced the grain yield of wheat in 1982-83 and 1983-84 (Table 12.1a) it was seen that use of 150 kg seed rate/ha alongwith 10 or 15 t/ha FYM resulted in comparable yields.

Similar type of effects were also noticed in respect of other yield contributing characters such as, number of effective tillers/metre running row length in all the three years of study. In case of other yield contributory characters such as number of spikelets/spike (Table 11.1c), number of grains/spike(Table 11.1d), 1000-grain weight(Table 11.1f) from the same interaction effect in the pooled analysis, it was observed that increase in seed rates at different levels of FYM decreased the spikelets/spike, number of grains/spike and 1000-grain weight. However, at fixed seed rate increase in FYM rates resulted in a significant increase in all the 3 yield contributing characters.

The nitrogen content and N uptake was also influenced by S x F interaction at 6 WAS in 1982-83 and 1983-84 (Table 13a). The highest N content and N uptake was observed at S_3F_3 during both the years.

The same interaction (i.e. S x F) also influenced the protein content in 1982-83 and 1983-84 as well as in pooled analysis (Table 14a). It was seen that increase in the rate of seed and FYM resulted in an increased in the protein contents.

6.7. Nutrient balance

The available soil N and P showed a deficit balance, whereas a positive balance of K was observed under all the treatments in all the three years of experimentation.

CONCLUSIONS

The following conclusions could be drawn from the results of this investigation which could be beneficial in attaining success with late sown wheat under rainfed conditions.

1. Use of higher seed rate @ 150 kg/ha which significantly increased the grain and straw yield to the tune of 36 and 49 per cent over 100 kg seed rate/ha, respectively and by 18 and 25 per cent over 125 kg/ha may be advocated.

2. Application of FYM @ 15 t/ha which increased the grain and straw yield to the extent of 32 and 34 per cent over 5 t/ha, respectively and by 11 and 9 per cent over 10 t/ha, respectively may be advocated.
3. Surface application of FYM significantly increased the grain and straw yield to the extent of 12 and 10 per cent over the incorporation of FYM into the soil. FYM should therefore, be applied on the soil surface for late sown rainfed wheat.
4. Increase in FYM application rates resulted in an increase in organic carbon, available N, P and K and total N and in decrease in soil pH and bulk density. Surface method of FYM application decreased the soil pH, bulk density but increased available N, P and K and total N in soil.
5. Seed rates x FYM rates interaction revealed that 125 kg seed rate/ha accompanied by 10 t/ha FYM resulted in statistically similar grain yield as is obtained at 150 kg seed rate/ha accompanied by 10 or 15 t/ha FYM. 150 kg seed rate accompanied by 15 t/ha FYM, however, also resulted in higher protein content in grains. For higher grain yield with better grain quality as well as better physical conditions of soil obtained at higher FYM rate it may, therefore, be recommended that under late sown rainfed conditions for the cultivation of wheat farmers should use 150 kg/ha seed rate accompanied by 15 t/ha FYM.

REFERENCES

Abdul-gallil, A.A. 1976. The response of wheat to different levels of nitrogen when applied through soil and foliage. Egyptian J. Agron. 1(2): 187-200.

Acharya, C.N. 1949. Manure production in villages. Indian Fmg. 10(4):9-13.

Acharya, C.L. and Bhagat, R.M. 1986. Fertilizer use efficiency through soil and water management practices in acid soils. Proc.FAI- NR Seminar (1986). CSWCRTI -Dehradun pp. 123-153.

Adams John E. 1966. Influence of mulches on runoff erosion and moisture depletion. Soil Sci. Soc. Amer.Proc. 30: 110-114.

Agarwal, S.K. 1974. Effect of rates of nitrogen, mulching and antitranspirants on water use efficiency, growth, yield and nutrient uptake by barley varieties under rainfed conditions. Ph.D Thesis, Division of Agronomy, I.A.R.I., New Delhi.

Agarwal, S.K.; Moolani, M.K. and Tripathi, H.P. 1971. Effect of sowing dates, levels of nitrogen and rate of seeding on dwarf wheat. Recent Advances in Crop Production. Institute of Agric.Sciences, Kanpur, U.P. 1989-193.

Agarwal, S.K.; Moolani, M.K. and Tripathi, H.P. 1972. Effect of sowing dates, levels of nitrogen and rate of seeding on dwarf wheat (Triticum aestivum L.). Indian J.agric.Sci. 42(1): 47-52.

Anonymous, 1970. A new technology for dryland farming. I.A.R.I. New Delhi.

Anonymous, 1985. Statistical Outline of H.P. Directorate of Economics and Statistics, H.P.Shimla-1 pp.99.

Anonymous, 1986. FAO Production Year Book (1985). Food and Agriculture Organisation of United Nations, Rome 39: 110.

Antonyuk, V. and Pogrebnyak, V. 1976. Effect of nitrogen fertilizers on grain yield and quality of winter wheat under irrigated conditions. Zemledelie Resp. Mizhvid, Temat. Nauk. Zb (1976). No.44:30-34 (c.f.Field Crop Abstr. 31(8): 4485,1978).

Argikar, G.P. and Patil, J.A. 1957. Agronomic practices for increasing wheat yield. Poona Agric.Coll. 47(4): 435-442.

Arnon, I. 1975. Physiological principles of dryland crop production. In Physiological Aspects of Dryland Farming. Gupta, U.S.(Ed.) Haryana Agric. University, Hissar, India. Mohan Primlani, Oxford and IBH Publishing Co., New Delhi.

Asana, R.D. and Mani, V.S. 1949. Photosynthesis in the ear of five varieties of wheat. Nature 163 :450-1.

Asana, R.D. and Sarin, M.N. 1968. Crop Physiology in India, ICAR Technical Bulletin. (Agric. Series) 16: 18-38.

Atkinson, H.J., Giles, G.R. and Desjardius, J.G. 1958. Effect of farm yard manure on the trace element content of soils and plant grown there on. Plant and Soil. 10: 32-36.

Attia, A.M.I. 1970. Effect of surface mulches and seed bed pattern on growth and yield of late sown wheat varieties. M.Sc.Thesis, I.A.R.I. New Delhi.

Austin, A. and Ahuja, V.P. 1974. Effect of nitrogen fertilization on the protein content and aminoacid composition of wheat grain. Act. Agronomica Academiae Scientarum Hungaricae. 23(1/2): 123-126.

Bains, G.S. 1953. Effect of commercial fertilizers and green manure on yield and nutritive value of wheat cereal chemistry. 47: 139-145.

Bains, S.S. 1969. Effect of seed beds with different directions and covers on grain yield of two varieties of wheat under late sown conditions. Half yearly report, Division of Agronomy, IARI, New Delhi.

Bains, S.S. and Bhardwaj, R.B.L. 1972. Standardization of Agricultural inputs. Indian Farming 4: 1-7.

Bains, S.S., Chaudhary, S.L. and Dayanand. 1968. Relay cropping- Possibilities and profits. Indian Fmg. 18(4): 31-34.

Bains, S.S., Singh, K.N. and Wayse,S.B. 1968. Salt tolerance studies with berseem with special reference to germination stand and yield sympo Water management. Indian Soc.Agronomy, IARI,New Delhi,pp.267-269.

Bains, S.S.,SWaminathan, M.S. and Singh, K.N. 1968. Success with late sown wheat. Bulletin,I.A.R.I.,New Delhi.

Balasubramanian,A., Shantaram, M.V., Sardeshpande,J.S., Saidaramappa,R. and Rangaswami, G. 1972. Studies on certain physico-chemical and microbiological properties of Tamil Nadu soils. Madras Agric.J. 59: 496-502.

Balla, A. 1981. FYM and fertilizer application trials at Martonvasar.1958-78. Field Crop Abstr. 34(8): 6348 p.712.

Balyk, G.S. 1981. The state of the plough layer determines yield.(c.f.Field Crop Abstr. 34(6), 463,1981).

Bansal, S.P., Giri, P.R. and Prihar,S.S. 1971. Effect of mulches on water conservation, soil temperature and growth of maize (Zea mays L.) and pearl millet (Pennisetum typhoides). Indian J.agric.Sci. 41(5): 467-473.

Basu, S.N. 1973. Research notes - Solubilization of rock phosphate. Fert. News. 18(3): 30-31.

Baver, L.D. 1972. Soil Physics. Chapman and Hall. London pp.193-248.

Bhardwaj, R.B.L. 1966. Report on agronomic studies on wheat varried out during 1966-67 proceeding of Sixth All India Wheat Research Workers Seminar (1967).

Bhardwaj, R.B.L. 1972. All India Wheat Improvement Programme. Report of Coordinated Agronomic Experiments, 1971-72.

Bhardwaj, R.B.L. 1973. Report of Coordinated Agronomic Experiments (1972-73) ICAR 12th All India Wheat Workshop held at IARI, New Delhi Sept. 3 to 8 (1973).

Bhardwaj, B.; Omanvak, P.K. and Bansal, S.K. 1982. Available potassium changes in a soil under continuous rotational cropping of rice, wheat and cow pea. J.Indian Soc. Soil Sci. 30: 99-101.

Bhardwaj, K.K.R. and Patil, R.B. 1982. Microbial recycling of organic matter. In 12th Int. Cong. Soil Sci. New Delhi. India. Part I: 258-268.

Bhardwaj, R.B.L. and Wright, B.C. 1967. New Agronomy for dwarf wheat. Indian Fmg. 27(11): 45-54.

Bhatia, K.S. and Shukla, K.K. 1982. Effect of continuous application of fertilizers and manures on some physical properties of eroded alluvial soil. J. Indian Soc. Soil Sci. 30: 33-36.

Bhowmick, H.D. and Raychaudhuri, S.P. 1953. Relative merits of organic manures and inorganic fertilizers. Proc. Nat.Inst. Sci. India. 19(1):35-43.

Bishnoi, K.C. and Gill, P.S. 1972. Performance of dwarf wheats under varying dates of sowing and seed rates. Haryana Agril. Univ.J. of Res.2(3):190-196 (c.f. Field Crop Abstr. 28(11):6978,1975).

Biswas, T.D., Gupta, S.K. and Naskar, G.S. 1961. Water stable aggregates in some Indian soils. J. Indian Soc.Soil Sci. 9: 299-307.

Biswas, T.D., Ingole, B.M. and Jha, K.K. 1969. Changes in physical chemical properties of the soil by fertilizer and manure application. Fert. News. 14(7):23 -26.

Biswas, T.D., Jain, B.L. and Bains, S.S. 1971. Proc.Int. Symp. Soil Fert. Evaln. New Delhi, 1,475, 831.

Biswas, T.D., Jain, B.L. and Mandal, S.C. 1971. Cumulative effect of different levels of manures on physical properties of soil. J.Indian Soc. Soil Sci. 19(1): 31-37.

Biswas, T.D., Pharande, K.S. and Naskar, G.C. 1967. Building up of soil structure by phosphate fertilization of legumes in a crop rotation. J. Indian Soc. Soil Sci. 15: 289-300.

Black, A.L. 1970. Soil water and soil temperature influences on dry land winter wheat. Agron. J. 62: 797-801.

Black, A.L. 1970. Adventitious roots, tillers and grain yields of spring wheat as influenced by N- P fertilization. Agron.J. 62(1):32-36,797-801.

Black, A.L. 1973. Crop residue soil tater and soil fertility related to spring wheat production and quality after fallow. Proc. Soil Sci.Soc. Amer. 37: 754-58, 943-46.

Black, C.A. 1965. Methods of soil analysis. Part II. Agron.9, Am.Soc.Agron. Medison, Wisconsin, U.S.A.

Boatwright, G.O. and Haas, J.J. 1961. Development and composition of spring wheat as influenced by nitrogen and phosphorus fertilization. Agron.J. 53: 33-36.

Bolaria, T.S., and Mann, H.S. 1964. Effect of mineral nutrition on the plant composition of two wheat varieties. Indian J.Agron.IX(1):30-40.

* Boon, R. and Venter, J.De. 1976. The value of Pigslurry as a fertilizer applied to cereals. Reveue de 1' Agriculture 29(6): 1457-79 (c.f. Field Crop Abstr. 30: 5137).

Borse, C.D. and Mahajan, V.K. 1980. Studies on the effect of sowing depth,seeding rate and nitrogen levels on growth and yield of wheat variety Sonalika. Indian J.Agron. 25(1): 45-50.

Boyd, D.A. 1952. Effect of seed rate on yield of cereals. Empire J.Expt.Agric. 20: 115-125.

Bower, G.D. 1970. Effect of soil temperature on root growth and on phosphate uptake along pinus radiata. Aust. J/Soil Res. 8: 31-42.

Bremner, J.M. 1960. Determination of nitrogen in soil by the Kjeldahl method. J.Agric.Sci. 55: 1-23.

Bremner, J.M. 1960. Determination of nitrogen by micro Kjeldahl method J.Agric. Sci. 55: 11-33.

Brengle, K.C. and Whitefield,C.J. 1969. Effect of soil temperature on the growth of spring wheat with and without straw mulch. Agron.J.61:377-379.

* Bunting, A.H. and Drennan, D.S.H. 1966. Some aspects of the morphology and physiology of cereals in the vegetative phase. pp.20-38 Bibl.82. (c.f.Field Crop Abstr. 19(3): 1899, 1966).

Cary, P. 1969. Some effects of root temperature on growth of citrus Finrs Newl. Lecton 1202: 6-10, 12-13 (c.f. Field Crop Abstr.1970/1106).

Chandanani, J.J. 1954. Manuring of wheat. Ind.J.Agric.Sci. 24: 195-211.

Chaudhri, M.S. and Khalid, S.A. 1961. Determination of most optimum seed rate spacing and sowing date for the newly evolved wheat strain H-63 for Hyderabad (Pakistan) region. Agric. Pakistan. 12(4): 709-714.

Chaudhary, P.C. and Chatterjee, B.N. 1967. Moisture conservation under mulches in the eroded terraced soils of Ranchi. J.Soil and Water Conserv. in India. 15(1&"): 61-71.

Chaudhary, M.S. and Vachhani, M.V. 1965. Long term effect of ammonium sulphate on the productivity status of rice soils. Indian J.Agron. 10: 145-151.

Chela, K.S. and Brar, H.S. 1975. Studies on the effect of sowing date and seed rates on the growth and yield of wheat Kalyan Sona. Indian J. Agron. 20(2): 87-90.

Cochran, W.G. and Cox, G.M. 1970. Experimental Designs. A.Wiley.Int.Ed.John Wiley andSons. Inc. New York. pp.203-211.

Coic, Y. and Alexinsky, W. 1954. Medium late and late application of nitrogen to winter wheat. C.R.Acad.Agric..Fr.1953.39(17): 782-88.

Collis-George, N., Davey, B.G., Scotter, D.R. and Williamson, D.R. 1963. Aust. J.Agric.Res. 14(1): 1-11.

Das, K. and Verma, S.C. 1957. Differential response of certain varieties of wheat to varying rates of seeding. J.Sci.Res.Banaras, 1956, 2: 175-180 (c.f. Field Crop Abstr. 10: (823), 1957).

Dastane, M.G. 1972. A practical manual for water use research in agriculture I.A.R.I. New Delhi. Navabharat Prakashan Budhwan Peth, Poona-2 India.

Datta, N.P. and Srivastava, S.C. 1963. Effect of organic matter on the intensity of phosphate bonding in some acid soils. J.Indian Soc.Soil Sci. 11: 189.

Dayanand 1971. Response of some varieties of wheat sown late to different forms of nitrogen, seed treatment and soil cover. Ph.D Thesis, Agra University, Agra.

Dayanand, Singh, K.N., Agarwal, K.N. 1977. Effect of varieties soil cover and form of nitrogen and seed soaking on uptake of major nutrients. Indian J.Agron. 22(2): 96-98.

Dayanand; Swaminathan, M.S. and Singh, K.N. 1972. Response of some varieties of wheat sown late to different forms of nitrogen, seed treatment and soil cover. Indian J.Agron. 17: 151-153.

Deb, D.L. 1976. Effect of organo minerals mixtures on crop yield and soil fertility. Fert. News. 21(9): 60-63.

Debnath, N.C. and Hajra, J.N. 1972. Transformation of organic matter in soils in relation to mineralization of carbon and nutrient availability J.Indian Soc. Soil Sci. 20: 95-102.

Dhiman, S.D. and Kalra, G.S. 1978. The response of triticale to seed rate and method of sowing under rainfed conditions. Indian J. Agron. 23(2): 161-62.

Dhingra, K.K.; Gill, G.S.; and Kaul, J.N. 1972. Agronomic studies on the late sown wheat. J. Res. Punjab Agri.Univ. Ludhiana. 11(3):262-268.

Dhoot, J.S.,Singh, N.T. and Brar, S.S. 1974. Polysaccharides in relation to soil aggregation under aerobic and anaerobic conditions. J.Indian Soc.Soil Sci. 22:217-219.

Drake, M. and Steckel, J.E. 1955. Solubilization of soil and rock phosphate are related to root cation exchange capacity. Soil Sci.Soc.Amer. Proc. 19: 449-450.

Dubey, S.K. and Lal, J.P. 1970. Yield behaviour of dwarf and tall wheat varieties under rate of nitrogen, seed rate and spacing. Indian J. Agron. 15: 136.

Eire, 1950. Influence of rate of seeding on yield of wheat and oats. J.Department Agric.Eire 1950. 47: 97-103.

Fernandez, E.R. and Laird, R.I. 1959. Effect of soil moisture and nitrogen manuring on yield and quality of wheat. Fol.Tec.27. Sec.Agric.(c.f.Field crop Abstr. 1959).

Ganai, B.A. 1983. Fertility management studies in rice-wheat rotation. Ph.D Thesis submitted to H.P.K.V.V, Palampur.

Gattani, P.D., Jain, S.V. and Satti, S.P. 1976. J. Indian Soc. Soil Sci. 24(3): 284-88.

Gaur, A.C., Neelakantan, S. and Dargan, K.S. 1984. Organic manures. ICAR,New Delhi.

Gaur, A.C. and Pareek, R.P. 1974. Organic acids in soil during decomposition of organic residues. Indian Nat. Sci. Acad. 40: B:68.

Gaur, A.C., Sadasivam, K.V., Mathur, R.S. and Magu, S.P. 1982. Agric.Wastes 4: 453.

Ghildyal, B.P. and Gupta, V.C. 1959. A study of biochemical and microbiological changes during the decomposition of Crotolaria juncea(Sunhemp) at different stages of growth in soil. Plant and Soil. 11:312-329.

Gill, H.S. and Meelu, O.P. 1980. Studies on the distribution of inorganic fertilizers with farm yard manure and their effect on soil fertility in rice-wheat rotation. Proc.Symp.Recycling of residue of agriculture and industry held at P.A.U. Ludhiana.pp.297-310.

Gupta, J.P. 1985. Studies on phosphate use efficiency and root CEC in wheat (S-308) as influenced by lime. FYM and phosphorus application in acid soils. Ph.D Thesis submitted to HPKVV, Palampur.

Gupta, M.B.S. 1966. Utilisation of phosphate by wheat as affected by the time of application in calcareous soil. J.Indian Soc.Soil Sci. 14(2): 133-7.

Gupta, J.P., Agarwal,P.K., Gupta, G.N. and Kaul,P. 1983. Effect of continuous application of FYM and urea on soil proportions and the bioduction of pearl millet on western Rajasthan. Indian J.agric.Sci. 53: 53-56.

Gupta, K.P., Kurchania, S.P. and Singh, S.P. 1968. A study on the dates and rate of seeding on the yielding abilities of dwarf wheats. Indian J. Agron. 13(4): 271-75.

Gomez, K.A. and Gomez, A.A. 1976. Statistical procedures for Agricultural research. A Wiley Inter Sciences. Publication John Wiley and sons. New York.pp.304-307, 643-645.

Halloran, G.M., and Lee, J.W. 1979. Plant nitrogen distribution in wheat cultivars. Australian J.Agric. Res. 30(5): 779-789.

Hanks, R.J., Bowers, S.A. and Bark, L.D. 1961. Influence of soil surface condition on net radiation, soil temperature and evaporation. Soil Sci. 91: 233-38.

Havangi, G.V. and Mann, H.S. 1970. Effect of rotations and continuous application of manures and fertilizers on soil properties under dry land farming condition. J. Indian Soc.Soil Sci. 18: 45-50.

Haworth, F. Cleaver, T.J., Bray, J.M. 1966. The effect of different manurial treatments on the yield and mineral composition of redbeet. J. Hort.Sci. 41: 243-255.

Holliday, D.J. 1960. Nitrogenous manuring of cereals in Britain Jeallotts Hill Res.Sta.Bull. 10: 1-39.

Holliday, R. 1960. Plant population and crop yield. Part I. Field Crop Abstr. 13: 159-67.

Hojjati, S.M. and Maleki, M. 1972. Effect of potassium and nitrogen fertilization on lysine, methionine, and total protein content in wheat grain. Agron.J. 64(1): 46-48.

Houque, M.S. and Stakova,S. 1978. Effect of FYM on the efficiency of triple superphosphate in an acid soil of Czechoslovokia, Polesh. J.Soil Sci. 11: 159-167.

Isenberg, F.M. and Olland, M.L. 1951. Comparative effect of various organic mulches and clean cultivation on yield of certain vegetable crops. Soil and Fert. 14(2): 864 (Abstr.).

Jacks, G.V., Brind, V.D. and Smith, R.1955. Mulching Tech. Communication No.49 of Commonwealth Bureau of Soil Science Farnham Royal Bucks England.

Jackson,M.L. 1967. Soil Chemical Analysis. Prentice Hall Inc.Englewood Cliffs, New Jersey, U.S.A. pp.331-334.

Jai Bhagwan, 1985. Phosphorus use efficiency of superphosphate with and without FYM and seed soaking in wheat in acid alfisol of Palampur,Ph.D. Thesis submitted to HPKVV, Palampur.

Jagtap,B.K. and Shingte,A.K.1982. Influence of azotobacter inocilation in conjuction with FYM economising use of fertilizer nitrogen to wheat. J. Indian Soc. Soil Sci. 30(2):210.

Kalita,P. and Choudhury,A.K.1984. Effect of varieties,seed size and seed rates on the yield of wheat. Indian J.Agron. 29(3): 287-290.

*Kanao,T., Hirano,J. and Eguchi,H. 1974. The prevention of lodging of wheat and barley by application of chlormequat soil mulching and other treatments. Bulletin of the Chugoku Nat. Agri.Expt. Sta.,A.1974. No.23: 1-26 (c.f. Field Crop Abstr.28(2): 649 p.62).

Kamla Singh and Singh,V. 1975. Effect of dates of sowing, seed rates and nitrogen levels on dwarf wheat Kalyan Sona. Indian J.Agron. 20: 76.

Kanwar,J.S. and Prihar,S.S. 1962a. Effect of continuous application of manures and fertilizers on some physical properties of Punjab Soil. J. Indian Soc. Soil Sci. 10: 243-248.

Kanwar,J.S. and Prihar,S.S. 1962b. Effect of continuous application of FYM and inorganic fertilizers on crop yield and properties of soil. J. Indian Soc. Soil Sci. 10: 109-20.

Kapur, M.L., D.S.Rana, and Sharma,K.N. 1981. Crop yields in rotation as influenced by farm yard manure and chemical fertilizers. Indian J. Agronomy. 26: 119-121.

Kar,S., Varade, S.B., Subramanayam, T.K. and Ghildyal, B.P. 1976. Soil physical conditions affecting rice root growth, bulk density and submerged soil temperature regime effect. Agron.J. 68: 23-26.

Kemmler,G. 1986. Plant nutrient balance under optimal fertilizer use and intensive cropping examples from India.Fert.New. 31: 29.

Khanna,P.K.,Jagannath,S.N.,Teneja,S. and V.P.Gopal,1975. Effect of organic manuring on some properties of sandy loam soils of Hissar.J. Indinn Soc.Soil Sci. 23(3): 380-83.

Khanna,S.S. and Stevensen, F.J. 1962. Metallo-organic complexes in soil. J. Soil Sci. 93: 298-305.

Khurana, S.R. and Guliani, R.S. 1973. Effect of sowing dates, nitrogen levels and seed rates on the yield of barley. Indian J.Agron.18:256.

Kiesselbach, T.A. 1926. The relation of seeding practices to crop quality. J. Amer. Soc. Agron. 18: 661-684.

Kiesselbach, T.A. and Lyness,W.E. 1948. Growing of winter wheat crop. Nemr Coll.Agric.Expt.Sta.Bull.389: 1-32.

Kingra,K.L., Foth, H.D., Robertson, L.S. and Brown, H.M. 1963. Effect of seeding rate, row spacing and rate and placement of fertilizer on winter wheat performance in Michigan, Agron.J. 55: 24-27.

Kohnke,H. and Werkhoven,S.N. 1963. Soil temperature and soil freezing as affected by an organic mulch. Soil Sci.Soc.Amer.Proc.27(1):13-17.

* Kuzentsova, Z.A. 1965. Effect of fertilizers on chemical composition of grain crops.A removal of nutrients by harvests. Agro.Khemiya No.11: 108-118 (c.f.Soils and Fert. 29(1914) 1966).

* Loginow,W. and Kaszubiak. 1964. The effect of FYM application on the available phosphorus and potassium in soil. Pam Putawaki.14:63-68 (c.f. Soil and Fert. 28(1911),1965).

Lund, Z.F. and Dass,B. 1980. Residual effect of dairy cattle manure on plant growth and soil properties.Agron. J. 72: 123-130.

Lyon, T.L., Buckman, H.O. 1953. The nature and properties of soil. McMillan and Co. New York pp.552-554.

Mahapatra, I.C. and Leelavathi, C.R. 1971. Response of wheat agro-techniques and their relationship with fertilizers in soil climate complexes. Fertil.News. 16(6): 38-46.

Mahendra, Singh and Sharma, K.C. 1976. Effect of sowing dates, nitrogen rates and seed rate on the yield attributes in dwarf wheat variety Kalyansona. Plant Sci. 5: 105-111.

Malik, D.S. 1969. Effect of various factors on yield and yield components in wheat and soybean. Diss.Abstr. 30(1): 27-28 (Univ.Illinois, Urbaka).

Mandal, L.N. and Jain, A.K. 1965. Effect of continuous application of organic manures and $(NH_4)SO_4$ in mulberry fields on some soil properties. J. Indian Soc.Soil Sci. 13: 37-42.

Mandal, L.N. and Pain, A.K. 1965. Effect of continuous application of organic manures and ammonium sulphate in mulbery field on some soil properties. Indian Soc.Soil Sci.13(1): 36-42.

Mangukia, M.R. 1953. The effect of weeds on the growth and yield of wheat under different seeding rates and different doses of nitrogenous fertilizers. Thesis submitted for Assoc.I.A.R.I. New Delhi-12.

Mann, G.S.,Jagirdar, H.S. and Sood,S.M. 1973. Effect of FYM on the yield and chemical composition of wheat crop. J.Res.Punjab Agri.Unive 10(4): 438-441.

Mathan, K.K., Sankaran, K., Kanakabhusini, N.K. and Krishnamoorthy, K.K. 1978. Effect of continuous rotational cropping on the organic carbon and total N content in a black soil. J. Indian Soc. Soil Sci. 26: 283-285.

Mathur, B.S. 1966. Influence of late sowing and spacing in the growth, development and yield of wheat. Indian J. Agron. 11: 345-350.

Maurya, P.R. and Ghosh, A.B. 1972. Effect of long term manuring and rotational cropping on fertility status of alluvial calcareous soils. J. Indian Soc. Soil Sci. 20(1): 31-43.

McCalla, T.M. and Duley, F.L. 1948. Stubble mulch studies, effect of sweet clover extract on corn germination. Science 108: 163.

Mehrotra, C.L. and Agnihotri, O.P. 1970. Effect of plant densities and sowing dates on fertilizer response in high yielding wheat, U.P. Inst. Agril. Sci. 158-162 (Field Crop Abstr. 27: 4839).

Mehta, U.R. and Mathur, B.N. 1972. Effect of sowing time and sowing date on yield of wheat in Rajasthan. Indian J. Agron. 17: 35-36.

Merrill, S., Kilby, W.W., and Greer, S.R. 1942. Numerical example of 3 x 3 x 2 partially confounded design. Experimental design, William, G. Cochran and Cox, M.G. 1977. Asia Publishing House, New Delhi, New York. Ist Indian Print. pp. 205-233.

Merwin, H.D. and M. Peech 1950. Exchangeability of soil potassium in sand, silt and clay fractions as influenced by the nature of complimentary exchangeable cations. Soil Sci. Soc. Am. Proc. 15: 125-128.

Mitra, A.K. 1949. Kanpur Agric. Coll. Magzine. 10: 22-26.

Modgal, S.C. 1979. Studies on tillage, straw incorporation and seeding management in rainfed lowland rice (wet season) and a tillage, straw incorporation and nitrogen fertilization in dry season rice. Terminal Res. Report. The Intl. Rice Res. Inst. Los Banos, Leguma, Philippines.

Moody, J.E., Jones, J.N. and Lillard, J.H. 1963. Influence of straw mulch on soil moisture, soil temperature and growth of corn. Proc. Soil Sci. Amer. 27: 700-03.

Nadagaudar, B.S. and Patil, S.V. 1973. Response of tall and dwarf wheats to time and rate of seeding under rainfed conditions. Mysore J. agric. Sci. 7: 499-509.

Nelson, E.C. 1960. Effect of plant population and nitrogen fertilizer rates on three varieties of irrigated spring wheat. Washington Agri. Expt. Sta. Bull. 611: 11.

Olsen, S.R., Cole, C.W., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with $NaHCO_3$, USDA Circ. 939: 1923.

Olsen, R.J., Hensler,R.F. and Attoe,O.J. 1970. Effect of manure application, aeration and soil pH on soil N transformation and on certain soil test values. Soil Sci.Soc.Amer.Proc. 34: 222-225.

Pal, M. 1969. Influence of maize stover incorporation in a maize-wheat rotation on soil properties. Indian J.Agron. 14:272-279.

Pareek, R.P. and Gaur, A.C. 1973. Release of phosphate from tricalcium and rock phosphate by organic acids. Curr.Sci. 42: 278-279.

Patil, B.R. and Bhardwaj, R.B.L. 1976. Effect of agrotechniques on the performance of different wheat varieties under late sown conditions. Indian J.agric.Sci. 46(2): 57-60.

Pendleton, J.W. and Dungan, G.H. 1960. The effect of seeding rate and rate of nitrogen application on winter wheat varieties with different characteristics. Agron.J. 52: 130-312.

Pharande, S.K. and Biswas, T.D. 1968. Buildup of soil structure by phosphate fertilization of a legume in a crop rotation. II.Structure and organic carbon status of the soils after harvest of succeeding non-leguminous crop (Wheat).J.Indian Soc.Soil Sci. 16: 187-192.

Piper, C.S. 1966. Soil and plant analysis. Univ. Adelaide,Australia.Hans Pub.Bombay India,pp.223-227.

Prasad, C.R., Shamisuddin, B.N. and Singh, B.N. 1971. Effect of continuous application of manures and fertilizers and lime on some chemical properties of acid red loam soils of Bihar Proc. Int. Symp. on soil Fert. Eval. 1: 865-872. Indian Soc. Soil Sci.,New Delhi India.

Prasad, B. and Singh, A.P. 1980. Changes in soil properties with long term use of fertilizers, lime and FYM. J. Indian Soc.Soil Sci.28:465-468.

Prasad, B., Sinha,K. and Sinha, M.P. 1982. Effect of continuous application of FYM and fertilizers on available soil and its uptake by potato. J. Indian Soc.Soil Sci. 30: 235-236.

Prihar, S.S., Singh, B. and Sandhu, B.S. 1968. Influence of soil and climatic environments on evaporation losses from mulches and unmulched pots. J.Res. PAU, Ludhiana, 5: 320-328.

Rai, S.D. 1966. A note on the response of wheat to seed rates dates and method of planting. Indian J.Agron. 11(4): 335-336.

Rajat De and Gajendra Giri. 1978. Effect of mulches and Kaolin foliar spray on wheat yield in dry lands. Indian J.agric.Sci. 48:334-337.

Ram, Sewa, 1975. Effect of agro-techniques on the performance of dwarf wheat varieties under late sown conditions. Ph.D thesis submitted I.A.R.I.- New Delhi.

Ram, S. and Bhardwaj, R.B.L. 1983. Effect of agro-techniques on performance of different wheat varieties under late sown conditions. Indian J. Agron. 28(1): 46-53.

Rana, V.S. 1980. A study on comparative performance of wheat (S-308) under different dates of sowing and seed rate. Thesis Abstr.6(2):89.

Randhawa, A.S. and Jolly, R.S. 1974. Response of wheat variety, Sonalika to sowing dates, row spacing and seed rates, J. Res. PAU,11:164-167.

Randhawa, A.S., Jolly, R.S. and Dhillon, S.S. 1977. Effect of seed rate and row spacing on the yield of dwarf wheat (Kalyan Sona) under different sowing dates. J. Res. XIV, 1: 5-7.

Rathi, K.S. and Misra, J.P. 1973. A note on the effect of seed rate and row spacing on the yield of 3 gene dwarf wheats. Indian J. Agron. 18: 525-526.

Rawson, H.M., Gifford,R.M. and Bremner, P.M. 1976. Carbon dioxide exchange in relation to sink demand in wheat. Planta 132(1):19-32.

Raychaudhuri, S.P. 1977. Integrated nutrient supply for increased soil productivity. J. Indian Soc.Soil Sci. 25: 444-456.

Read, D.W.L. and Beaton, J.D. 1963. Effect of fertilizers temperature and moisture on germination of wheat. Agron. J. 55:287-290.

Roy, P.K., Sinha, R.N. and Prasad, R. 1969. Relationship of plant characters attributing to the yield of dwarf wheat varieties. Indian J.Agron. 14(3): 232-35.

Russel, E.W. 1973. Soil condition and plant growth. 10th Ed. Longman Green and Co. New York,pp.30-67., 802-807

Sachan, S.S. 1976. Effect of mulching and fertilization on growth and yield of wheat. Indian J.Agron. 21(4):484-486.

Sahu, B.N. and Nayak, B.C. 1971. Proc. Int. Symp. soil fertilizer evaluation. New Delhi. Indian Soc. Soil Sci. New Delhi.

Sandhu, H.S., Gill, G.S. and Brar, S.S. 1975. Influence of sowing dates and seed rates on the performance of wheat varieties Kalyan Sona, HD-1941 and WL 2112. Indian J.Agron. 20(1):17-20.

Schnieder, E. 1980. Influence of organic manuring on the size and reliability of grain yield in long term trials on sandy sites. Field Crop Abstr. 33(7): 549.

Sen, S. and W.C. Bonde, 19.62. Effect of time of application of FYM at different levels on wheat. J. Indian Soc. Soil Sci. 10: 61-66.

Sharma, K.C. 1967. Influence of date of sowing seed rate and nitrogen fertilizer on performance of dwarf wheats. Symp. on Agronomy of new crop varieties under irrigated and unirrigated conditions held at Pantnagar University Oct. 26-28, 1968.

Sharma, B.L. 1971. Response of nitrogen and phosphorus on growth, grain yield, nutrient, yield and quality of tall and dwarf wheats. Ph.D Thesis submitted to IARI, New Delhi.

Sharma, H.L. 1983. Studies on the utilization of crop residues, farm yard manure and nitrogen fertilization in rice-wheat cropping system under sub-temperate climate. Ph.D thesis submitted to HPKVV, Palampur.

Sharma, R.R. 1986. Studies on seed rate, row spacing and soil moisture conservation practices on rainfed wheat (Triticum aestivum L.). Ph.D Thesis submitted to HPKVV, Palampur.

Sharma, K.C., Kumar, N and Singh, M. 1971. Uptake of N, P_2O_5 and K_2O in dwarf wheats as influenced by phosphorus and potash at farmers field. Indian J. Agron. 16(3): 276-280.

Sharma, K.C. and Singh, M. 1972. Yielding abilities on dwarf wheat at different dates of sowing and seed rates. Indian J. agric. Sci. 42: 1110-1115.

Shinde, D.A. and Ghosh, A.B. 1971. Effect of continuous cropping and manuring on crop yield and characteristics of a medium black soil. Symp. Proc. Int. Soil Fertil. 1: 905-916.

Shukla, S.K. and Misra, N.M. 1979. Effect of seed size and seed rates on growth and yield of wheat. Seed & Farmer. 5(10: 39-43.

Singh, G. 1963. Studies on the uptake and recovery of N, P_2O_5 by wheat. Indian J. Agron. 7(3): 215-230.

Singh, G. 1965. Dry matter and grain yield in relation to level of N and seed rates of wheat. Indian J. Agron. 10(3): 261-65.

Singh, R.A. 1980. Soil physical analysis. Kalayani Publishers, Ludhiana, New Delhi.

Singh, S.S. and Alam, L.N. 1944. The effect of certain external factors upon the growth of wheat. Ind. Aca. Sci. Sec. B. 19(3): 29-64.

Singh, R.P. and Anderson, R.G. 1973. Nitrogen and dry matter accumulation in dwarf wheat varieties as influenced by nitrogen fertilization. Indian J. agric. Sci. 43: 570-579.

Singh, A., Bhardwaj, R.B.L., Gautam, R.C. and Singh, M. 1971. Optimum seed rate and nitrogen requirement of dwarf wheat varieties under different dates of sowing. Indian J.Agron. 16: 23-27.

Singh, S.D. and Gupta, M.L. 1969. Relative efficiency of nitrogenous fertilizers in the presence and absence of phosphorus on wheat.I. Yield and grain protein content. Indian J.Agron. 14:262-270.

Singh, S.D. and Gupta, M.L. 1970. Relative efficiency of nitrogenous fertilizers in the presence and absence of phosphorus on wheat. II. Developmental composition. Indian J.Agron. 15(2):118-124.

Singh, K.N., Misra, B.N. and Mahabir Prasad,1975. Effect of time of sowing, seed rate and seed soaking on grain yield of rainfed barley. Indian J.Agron. 20: 26-28.

Singh, H. and Sharma, H.C. 1981. Effect of organic matter and Gypsum application on grain yield of wheat irrigated with Brackish water. Indian J. Agron. 26(4): 454-456.

Singh, S.P. and Singh, R.R. 1969. Uptake of N by wheat as influenced by levels and methods of N application.Agra Univ.J.Res.11: 1-6.

Singh, K. and Singh,V. 1975. Effect of dates of sowing, seed rate and nitrogen levels on dwarf wheat Kalyan Sona. Indian J.Agron 20: 76.

Singh, L. and Singh, S. 1981. Influence of root cation exchange capacity on nutrient composition of shoot and grain of rice and wheat.J. Indian Soc. Soil Sci. 29: 288-232.

Singh, L., Verma, R.N. and Lohia,S.S. 1980. Effect of continuous application of FYM and chemical fertilizers on some soil properties. J. Indian Soc. Soil Sci. 28(2): 170-172.

Sinha, R.N.& Singh, S.N. 1970. Response of dwarf wheat varieties to different seeding rates and depth of sowing. Indian J.Agron.15(4):383-384.

Smika, D.E., and Ellis, R.Jr. 1971. Soil temperature and wheat straw mulch effects on wheat plant development and nutrient concentration. Agron.J. 63: 388-91.

Solomn, S. and Patil, J.A. 1958. 25 years of crop research. Res. Farmer.9:3-8.

Spillane, P.A. 1962. The effect of nitrogenous fertilizers on the quality of Atle wheat. Irish J.Agric.Res. 1(3): 237-250.

Srinivasan, A. 1943. Conservation of humus in tropical soils. Nature,152:572-573.

Stevens, J.G.T. 1965. Wheat seeding rate. Od Agric.J. 91(1): 40-42.

Stickler, F.C. 1962. Row width and seeding rate as factors influencing winter wheat yield and components of yield. Trans. Kans.Acad.Sci.1961, 64(1):1-6 (Kanas Agric.Expt.Sta. Manhathan) (c.f. Field Crop Abstr. 15(3): 181 No.1196).

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. Curr.Sci. 25: 259-260.

Sumbali, G.L. and Sharma, S.P. 1973. A note on yield potentials of dwarf wheat varieties under different seeding rate. Indian J.Agron. 18:400-402 .

Suput, M. 1966. Effect of seed rate on yield of some wheat varieties. Field Crop Abstr. 22(1): 19, 1969. Zbon.Rad.Poliqoprive.Fak.Univ.Beaqr.

Tandon, R.K. and Mishra, M.P. 1960. Effect of seeding rate on the growth, development and yield of wheat. Kanpur.Coll.J. 19:192.

Terman, G.L. 1979. Yield and protein content of wheat grain as affected by N and environmental growth factors. Agron.J. 71:437-440.

Tomar, N.K., Gupta, A.P. and Khanna, S.S. 1984. Evaluation of rock phosphate, superphosphate mixtures by incubation in organic matter for efficient use in wheat. Fertil.News 29(2): 37-38.

Upadhyay, U.C. and Choudhari, C.S. 1971. Effect of spacing, seed rate on variety Sonalika S-308. Indian J.Agron. 16: 238-239.

Upadhyay,U.C. and Kuberkar, S.Y. 1980. Influence of seed rate spacing and varieties on yield of wheat. Indian J.Agron.25(1): 32-36.

Verma, S.D. 1979. Characteristics and genesis of soils of Himachal Pradesh. Ph.D Thesis submitted to HPKVV, Palampur.

Vez, A. 1972. The influence of sowing rate, sowing date and nitrogen on yields of spring wheat. Revere Suisseed' Agriculture 3(6): 142-144.

Vyas, M.K. and Motiramani, D.P. 1971. Effect of organic matter, silicate and moisture level on availability of phosphate.J.Indian Soc.Soil Sci. 19: 39-43.

Waggoner, P.E. 1960. Mulches and energy balance at the soil surface. Trans. 7th International Congress Soil Sci. 1: 164-68.

Waldren, R.P. and Flowerday, A.D. 1979. Growth stages and distribution of dry matter, N, P and K in winter wheat. Agron. J. 71(3): 391-96.

Walkley, A. and Black, I.A. 1934. An examination of the Dagtjara reff method for determining soil OM and a proposed modification of the chromic acid titration method. Soil Sci. 37: 29-38.

Warsi, A.S. and Fateh Singh, 1975. Effect of sowing time of rainfed barley in relation to seed rate and seed soaking in Bundelkhand region of Uttar Pradesh. Indian J.Agron. 20(3): 295-296.

Whitehead, D.C. 1963. Some aspects of the influence of organic matter on soil fertility. Vol. 26 page 217-223, Soil and Fertilizer.

Woodword, R.W. 1966. Response of semi-dwarf spring wheats to nitrogen and phosphorus fertilizers. Agron.J. 58(1): 165-66.

Yaduvanshi, H.S., Kanwar, B.S. and Tripathi, B.R. 1984. Nitrogen, phosphorus and potassium balance under continuous manuring in multiple cropping sequence in an acid Hill soil. J. Indian Soc.Soil Sci. 32: 101.

Zhezher, L.V. and Surorov, V.P. 1980. Effect of different methods of FYM application on spring wheat yield. Agrokhimiya 8: 122-124 (c.f. Field Crop Abstr. 35: 38, 1982).

APPENDIX I

Mean weekly meteorological data for the period of experimentation (10 December 1982 to 27th May, 1985)

Standard week No.	Period	1982-83 Temperature °C Max.	Min.	Relative humidity (%)	Sun-shine hours	Rain-fall (mm)	1983-84 Temperature °C Max.	Min.	Relative humidity (%)	Sun-shine hours	Rain fall (mm)	1984-85 Temperature °C Max.	Min.	Relative humidity (%)	Sun shine hours	Rainfall (mm)
50	10/12-16/12	17.4	7.9	65.0	5.5	0.0	17.1	6.6	38.0	5.2	0.0	16.0	6.5	72.0	4.3	63.7
51	17/12-23/12	16.9	6.7	47.0	4.6	0.0	16.0	6.3	53.0	4.5	2.6	17.0	4.7	54.7	8.4	0.0
52	24/12-31/12	14.7	3.5	64.0	5.8	0.6	13.3	2.5	59.0	6.3	7.1	13.9	6.5	60.2	3.5	30.4
1	1/1 - 7/1	13.9	4.2	66.0	6.0	0.0	12.4	2.6	62.0	5.4	4.4	11.5	3.0	69.4	3.7	45.7
2	8/1 -14/1	13.0	2.7	61.0	6.3	1.8	15.0	5.2	50.0	6.5	21.5	14.2	3.9	62.2	7.6	0.4
3	15/1 -21/1	14.8	4.0	49.0	6.4	4.2	12.0	3.3	60.0	4.2	3.6	15.0	6.0	77.4	3.3	4.0
4	22/1 -28/1	15.3	5.0	69.0	3.5	118.9	11.7	2.0	52.0	4.5	3.0	14.8	4.3	55.8	6.5	22.6
5	29/1 - 4/2	10.9	1.4	71.0	6.4	12.8	16.7	5.2	45.0	6.4	23.2	15.5	5.8	68.7	6.4	20.2
6	5/2 -11/2	14.1	3.4	55.0	7.6	3.2	14.5	4.1	41.0	5.6	0.0	15.7	4.7	89.0	9.0	0.0
7	12/2 -18/2	14.8	5.8	65.0	1.7	82.3	16.2	6.4	45.0	4.6	8.6	17.9	5.7	87.2	9.5	0.0
8	19/2 -25/2	16.0	5.4	66.0	6.5	89.2	10.1	0.1	70.0	4.3	106.2	19.4	7.5	54.0	8.2	7.2
9	26/2 - 4/3	16.0	6.5	59.0	5.6	22.0	18.0	6.5	45.0	10.1	0.0	23.6	11.2	50.7	8.8	0.0
10	5/3 -11/3	19.7	10.0	52.0	5.0	5.8	21.4	10.4	40.0	8.3	0.0	23.7	12.3	43.0	6.5	0.0
11	12/3 -18/3	20.7	10.0	46.0	6.3	Trace	24.0	13.0	39.0	4.9	13.6	23.0	11.6	87.4	5.3	0.0
12	19/3 -25/3	17.5	6.7	57.0	3.6	61.2	23.2	12.7	48.0	9.7	0.0	23.1	10.8	82.2	6.9	17.8
13	26/3 - 1/4	20.6	8.5	56.0	6.4	26.6	25.8	14.1	54.0	7.5	22.2	24.4	13.0	87.0	5.5	8.6
14	2/4 - 8/4	23.1	11.2	56.0	5.4	30.0	24.0	11.5	38.7	7.1	11.4	22.9	12.1	76.8	6.4	19.2
15	9/4 -15/4	19.6	9.6	63.0	4.5	50.0	25.1	13.8	35.8	9.2	3.6	22.7	12.6	75.0	6.4	54.4
16	16/4 -22/4	20.4	9.1	57.0	6.6	69.6	27.5	16.2	40.1	5.1	8.0	28.6	16.9	42.1	11.2	5.6
17	23/4 -29/4	27.0	15.5	49.0	9.7	12.2	27.3	16.7	43.2	5.8	4.0	28.8	16.4	31.1	7.8	1.0
18	30/4 - 6/5	27.9	15.0	41.0	8.6	22.0	30.5	17.6	29.0	10.8	0.0	29.4	16.6	30.0	8.3	13.4
19	7/5 -13/5	28.1	16.9	56.0	7.9	17.7	32.5	20.1	31.0	9.2	9.6	29.6	18.4	65.0	4.9	21.2
20	14/5 -20/5	26.4	16.4	71.0	5.6	56.3	32.6	20.8	26.5	10.2	16.2	31.4	18.9	46.0	10.6	3.0
21	21/5 -27/5	25.2	15.5	58.0	6.4	52.6	35.0	23.9	29.7	10.5	0.0	31.8	20.2	55.0	9.0	14.0

APPENDIX II

Analysis of variance for days for germination‡ and number of shoots/m row length at various stages of growth

Source of variation	d.f.	Mean sum of squares					
		Days for germination	Weeks after sowing (WAS)				
			6	8	10	12	Harvest
				1982-83			
Rep.	3	2.08	8.20	23.08	56.83	30.33	34.38
B R	8	0.19	111.72	27.76	111.41	93.41	122.41
S	2	6.05*	3729.50*	1373.37*	3198.15*	2219.79*	3858.85*
F	2	3.01	48.29	336.50*	2051.25*	618.00*	239.05*
M	1	86.68*	690.68*	217.01*	1386.80*	997.55*	141.68
SF	4	0.16	50.95	617.42*	500.22*	79.75*	150.25*
SM	2	2.05	579.55*	9.35	37.60	237.60*	169.01*
FM	2	0.26	753.10*	42.06	259.75*	544.89*	757.56*
SFM	4	0.38	201.05*	59.81	693.34*	182.35*	263.92*
Error	43	1.47	32.90	32.55	37.97	25.88	40.67
				1983-84			
Rep.	3	1.01	5.59	32.76	34.90	11.02	16.61
B R	8	0.26	63.79	120.75	40.68	63.57	44.72
S	2	9.18*	244.68*	229.84*	353.35*	1680.18*	373.72*
F	2	4.76*	149.68*	754.68*	852.76*	85.43*	228.39*
M	1	74.01*	512.00**	410.89*	455.02*	420.50*	512.00*
SF	4	0.34	121.84*	694.87*	119.47*	265.12*	152.76*
SM	2	3.18*	216.54*	15.26	105.01	161.54*	21.50
FM	2	0.26	96.29*	356.51*	315.09*	28.04	45.50*
SFM	4	0.23	65.80*	44.74	98.91	39.68	40.33*
Error	43	0.83	21.66	22.72	45.31	19.22	13.76
				1984-85			
Rep.	3	1.05	7.20	26.60	7.50	90.53	9.16
B R	8	1.08	37.79	92.69	17.43	93.40	101.37
S	2	0.87	1415.05*	356.54*	185.06*	206.01	113.39*
F	2	4.62*	830.89*	880.29*	444.76*	726.93*	126.93*
M	1	80.22*	786.72*	231.13*	76.06	171.12	506.68*
SF	4	0.11	59.17*	301.25*	170.10*	134.80*	92.05*
SM	2	0.14	379.06*	439.12*	776.05*	63.29	91.55*
FM	2	0.18	139.39*	35.79	166.09*	209.29	926.01*
SFM	4	0.93	23.97	108.79*	78.66*	629.43*	160.81*
Error	43	0.92	13.30	27.27	20.31	73.63	26.70

‡ Days for germination from sowing till constant shoots.

APPENDIX III

Analysis of variance for treatment effects on plant height at various stages of crop growth

Source	d.f.	Mean sum of squares					
		Weeks after sowing (WAS)					
		6	9	12	15	18	Harvest
				1982-83			
Rep.	3	1.57	0.29	21.00	15.20	14.47	7.85
B R	8	0.57	0.55	12.60	10.94	18.94	19.25
S	2	0.63	12.19*	35.14*	28.32*	124.23*	4.95
F	2	0.57	21.40*	326.24*	130.93*	240.53*	138.75*
M	1	1.33*	2.00*	47.22*	74.08*	94.94*	185.22*
SF	4′	0.44	3.30*	9.53	7.02	16.77	20.07
SM	2	1.29*	0.18	2.13	23.88*	5.96	21.03
FM	2	0.37	0.77	26.37	9.40	21.47	28.86*
SFM	4′	0.92*	1.04	6.90	12.06	7.89	4.91
Error	43	0.30	0.45	9.47	5.73	7.73	8.41
					1983-84		
Rep.	3	0.77	2.85	14.27	1.44	37.97	7.32
B R	8	0.21	3.88	28.57	8.38	7.20	3.22
S	2	1.00*	13.98*	111.50*	104.95*	45.57*	41.47*
F	2	0.29	7.59*	4.42	178.42*	98.57*	43.02*
M	1	3.48*	0.16	44.08*	174.04*	38.42*	83.87*
SF	4′	0.28	10.86*	41.41*	33.30*	26.01*	14.52
SM	2	0.44	7.63*	22.75*	61.48*	12.19	16.00
FM	2	0.81	1.92	9.58	11.16	21.74	0.20
SFM	4′	0.15	5.22*	4.00	9.20	4.72	11.29
Error	43	0.23	1.00	5.76	4.06	7.41	10.89
					1984-85		
Rep.	3	3.30	71.65	443.78	67.85	18.27	12.52
BR	8	3.55	34.59	5.59	15.23	11.70	18.29
S	2	3.19	84.72	22.24	53.14*	12.09	41.67*
F	2	37.23*	95.38	182.55*	154.09*	109.93*	96.65*
M	1	0.86	0.92	59.29	39.67	121.89*	173.17*
SF	4′	1.27	17.65	77.76	33.97	50.00*	60.06*
SM	2	1.80	36.69	8.11	4.84	5.68	38.63*
FM	2	1.47	9.45	26.62	13.29	2.43	70.59*
SFM	4′	1.13	26.49	31.75	6.26	13.99	34.21*
Error	43	1.85	39.46	39.85	13.27	11.00	10.08

APPENDIX IV

Analysis of variance for treatment effects on green matter production (g/m) at various stages of crop growth

Source	d.f.	Mean sum of squares				
		Weeks after sowing				
		6	10	14	18	Harvest
				1982-83		
Rep.	3	4.13	42.48	118525.00	1988.33	6271.33
B R	8	1.98	42.16	119190.00	1406.50	1763.87
S	2	165.84*	2441.08*	190433.50	31380.00*	48717.00*
F	2	21.49*	616.39*	1533810.00*	10378.00*	7266.00*
M	1	34.91*	1339.17*	57561.00	20371.00*	35514.00*
SF	4	11.54*	7.10	118357.50	950.00	462.50
SM	2	0.39	0.46	138603.00	1664.50	1543.00
FM	2	13.35*	122.64*	100349.50	7420.51*	1825.00
SFM	4	5.40*	57.40	106489.81	2479.71*	4226.28
Error	43	1.62	22.69	124983.81	665.74	1978.88
				1983-84		
Rep.	3	0.95	28.23	887.33	380.66	1759.00
B R	8	2.60	16.27	902.25	618.25	408.50
S	2	223.38*	1899.91*	80899.50*	27784.00*	33743.00*
F	2	100.43*	761.97*	26948.00*	3157.00*	13907.00*
M	1	125.98*	1348.53*	14235.00*	12520.00*	17125.00*
SF	4	5.62*	63.35*	1320.00	112.50	186.25
SM	2	8.98*	44.69*	1732.50	5930.00*	3767.50*
FM	2	1.42	80.62*	1284.00	3138.00*	4651.00*
SFM	4	6.24*	96.96*	1461.51	446.75	1761.91*
Error	43	1.69	11.28	630.92	427.51	365.37
				1984-85		
Rep.	3	3.39	14.23	8563.33	1272.00	512.00
B R	8	2.01	19.30	808.12	910.25	1713.25
S	2	234.94*	2633.63*	51691.00*	25644.00*	49247.50*
F	2	78.99*	655.18*	12287.00*	1381.50	18603.00*
M	1	94.75*	833.32*	15845.00*	7724.00*	20335.00*
SF	4	6.32*	92.37*	1712.50	177.50	674.00
SM	2	5.78*	64.52*	1869.50	4071.00*	2696.50
FM	2	0.41	18.24	7583.50*	3588.00	6059.00*
SFM	4	7.20*	23.57*	2145.14	933.04	420.84
Error	43	1.25	8.23	2189.21	1230.57	871.17

APPENDIX V

Analysis of variance for dry matter accumulation (g/m^2) at various stages of growth.

Source	d.f.	Mean sum of squares				
		Weeks after sowing (WAS)				
		6	10	14	18	Harvest
				1982-83		
Rep.	3	0.24	2.43	8.80	197.33	122290.33
B R	8	0.24	2.25	54.36	192.37	1225.62
S	2	9.74*	184.58*	51.30*	12071.00*	25976.50*
F	2	1.81*	60.69*	955.10*	6695.00*	5743.50*
M	1	5.10*	130.30*	4353.60*	16296.00*	29864.00*
SF	4'	0.19	0.56	98.25*	589.50*	265.25
SM	2	0.39	0.19	50.50	63.50	144.50
FM	2	0.58*	9.34*	376.30*	2777.00*	272.00
SFM	4'	0.13	6.78*	141.27*	400.11*	2874.92
Error	43	0.87	1.40	30.15	113.64	1201.00
				1983-84		
Rep.	3	0.53	0.93	66.83	256.00	2319.63
B R	8	0.31	1.45	88.90	77.12	200.55
S	2	11.36*	125.08*	10373.85*	6447.00*	13423.30*
F	2	2.78*	49.74*	5610.35*	751.00*	5208.10*
M	1	7.67*	96.37*	3717.60*	5298.00*	7704.80*
SF	4'	0.36*	2.54*	240.50*	23.25	43.75
SM	2	0.31*	2.43*	90.35	1205.00*	391.95
FM	2	0.13	5.18*	459.95*	1082.00*	3273.00*
SFM	4'	0.14	6.74*	262.00*	32.00	689.52
Error	43	0.78	0.66	69.95	65.04	486.75
				1984-85		
Rep.	3	1.63	0.93	1330.23	485.66	264.66
B R	8	0.30	2.35	232.00	302.62	913.50
S	2	15.08*	209.51*	11278.05*	7541.50*	33130.00*
F	2	3.03*	59.27*	4072.20*	794.50	13557.50*
M	1	3.25*	79.27*	5461.20*	3789.00*	14839.00*
SF	4'	0.19	8.64*	268.50	194.50	361.25
SM	2	0.29	3.50*	152.95	809.50	1845.50*
FM	2	0.41	2.74*	1068.95*	930.00	4122.00*
SFM	4'	0.20	2.32*	613.21	296.09	266.82
Error	43	0.15	0.79	390.75	341.01	462.34

APPENDIX VI

Analysis of variance for per cent dry matter production at various stages of growth. (Transformed data)

Source	d.f.	Mean sum of squares				
		Weeks after sowing(WAS)				
		6	10	14	18	Harvest
				1982-83		
Rep.	3	0.11	0.50	0.15	0.88	0.82
B R	8	0.49	0.11	0.68	0.80	0.41
S	2	0.55*	0.25*	0.45*	1.44*	1.79*
F	2	0.33*	0.35*	0.58*	1.88*	3.85*
M	1	0.19*	0.67*	2.94*	12.31*	10.42*
SF	4'	0.16	0.13*	0.35	0.11	0.36
SM	2	0.37	0.67	0.22*	1.51*	0.91
FM	2	0.24*	0.35	0.50	0.40	0.55
SFM	4'	0.48	0.16*	0.22	0.73	0.95
Error	43	0.46	0.39	0.93	0.31	0.31
				1983-84		
Rep.	3	0.32	0.41	0.73	0.59	1.00
B R	8	0.22	0.19	0.35	0.48	0.19
S	2	0.59*	0.31*	0.18	0.35*	6.59*
F	2	0.13	0.13*	1.39*	0.50*	1.86*
M	1	0.25*	0.48*	3.47*	3.42*	2.40*
SF	4'	0.11	0.23	0.49	0.22	0.44
SM	2	0.97	0.33	0.11	0.23*	0.25
FM	2	0.66	0.27	0.55	0.28*	0.20
SFM	4'	0.10	0.40	0.16	0.30	0.57
Error	43	0.95	0.18	0.35	0.35	0.22
				1984-85		
Rep.	3	0.10	0.86	1.19	0.50	0.26
B R	8	0.38	0.42	1.39	0.95	0.10
S	2	0.13*	0.22*	1.14	0.63*	7.92*
F	2	0.15	0.18*	6.38*	0.33*	4.32*
M	1	0.30	0.28*	0.11	2.66*	4.93*
SF	4'	0.13	0.82	0.85	0.26*	0.91*
SM	2	0.57	0.15	1.46	0.30*	1.61*
FM	2	0.20	0.11	0.15	0.10	0.78*
SFM	4'	0.85	0.46	1.69	0.84	0.52*
Error	43	0.21	0.32	1.60	0.67	0.79

APPENDIX VII

Analyses of variance for 50, 100 per cent heading and days to maturity.

Source	d.f.	Mean sum of squares		
		Days to 50% heading	Days to 100% heading	Days to maturity
		1982-83		
Rep.	3	5.52	15.79	31.96
B R	8	4.66	6.09	75.01
S	2	108.80*	26.93*	46.95*
F	2	11.86	8.39	106.55*
M	1	21.33*	7.35	186.90*
SF	4'	3.62	3.85	342.12*
SM	2	0.50	4.18	194.75*
FM	2	4.54	2.05	146.75*
SFM	4'	5.70	4.75	76.20*
Error	43	3.92	5.27	3.12
		1983-84		
Rep.	3	6.60	24.16	3.83
B R	8	27.02	40.25	19.68
S	2	41.62*	19.01	8.65*
F	2	88.87*	40.05*	77.55*
M	1	0.68	48.35*	11.70*
SF	4'	8.05	74.45*	18.87*
SM	2	17.93	100.93*	230.70*
FM	2	41.93*	99.39*	60.40*
SFM	4'	49.07*	9551*	68.43*
Error	43	7.88	6.09	2.00
		1984-85		
Rep.	3	1.51	6.66	9.16
B R	8	4.69	2.83	1.12
S	2	8.59	40.04*	19.35*
F	2	70.26*	17.54*	48.60*
M	1	16.05*	93.38*	110.00*
SF	4'	8.47	1.70	4.92
SM	2	2.10	0.18	0.20
FM	2	4.35	1.27	0.35
SFM	4'	5.83	1.88	1.78
Error	43	3.80	4.17	4.60

APPENDIX VIII

alyses of variance for yield contributing characters.

urces -	d.f.	No.of effective tillers per metre 1982 -83	1983 -84	1984 -85	Spike length (cm) 1982 -83	1983 -84	1984 -85	Pooled	Spikelets per spike 1982 -83	1983 -84	1984 -85	Pooled	No.of grains per spike 1982 -83	1983 -84	1984 -85	Pooled	1000-grain weight(g) 1982 -83	1983 -84	1984 -85	Pooled
	3	164.56	7.72	33.20	0.49	0.32	5.78	0.65	0.39	3.13	3.86	1.77	5.85	0.91	2.41	0.44	3.48	0.62	7.66	0.56
	8	80.05	46.09	20.29	0.10	0.29	0.51	0.94	0.92	0.67	1.97	0.48	4.38	15.65	4.27	2.65	3.00	0.95	11.87	1.83
	2	416.72*	214.85*	212.60*	2.42*	1.06	0.61	0.56*	4.26*	2.14	0.80	2.10*	43.33*	18.60*	12.06*	20.66*	5.28*	1.72	5.01	3.58*
	2	183.18*	707.56*	15.26	0.30	1.18	1.00	0.49*	0.84	3.01	1.40	1.60*	14.99*	13.90*	47.52*	22.55*	12.98*	6.04*	26.11*	13.78*
	1	715.68*	150.23*	150.23*	2.27*	1.75	3.30*	2.40*	26.76*	4.70	0.50	7.20*	26.03*	71.20*	51.00*	47.59*	23.80*	21.12*	0.65	11.82*
	4	139.30*	99.03*	148.65*	0.28	0.21	0.15	0.30	8.55*	1.53	0.74	1.00*	11.62*	30.15*	16.92*	6.49*	6.04*	2.41	40.97*	4.29*
	2	49.55	10.51	76.51	0.36	0.13	0.94	0.24	0.45	0.22	0.48	0.21	0.27	33.76*	8.32*	7.93*	0.85	1.38	14.63	1.44
	2	805.09*	133.55*	445.43*	0.30	0.31	0.16	0.17	0.82	0.10	0.16	0.11	1.62	10.59*	3.81	0.25	5.36*	0.99	36.73*	5.25*
M	4	93.80	122.80*	36.38	0.20	0.34	0.13	0.39	1.06	0.61	1.00	0.18	0.61	29.47*	30.53*	12.63*	3.50*	0.67	18.93*	4.22*
ror	43	51.46	10.00	31.45	0.17	0.54	0.80	0.10	0.76	1.23	0.96	0.28	3.18	3.22	1.49	0.71	1.17	1.62	7.07	1.08

APPENDIX IX

Analyses of variance for grain yield, straw yield and harvest index.

Source	d.f.	Mean sum of squares			
		1982-83	1983-84	1984-85	Pooled
			Grain yield		
Rep.	3	69.15	11.26	172.74	41.56
B R	8	49.47	7.83	10.49	11.12
S	2	127.21*	27.54*	527.48*	161.63*
F	2	157.09*	87.14*	153.04*	127.42*
M	1	36.22	25.35*	182.59*	60.79*
SF	4'	36.30*	18.84*	3.75	4.17
SM	2	1.17	0.72	0.84	0.50
FM	2	0.89	2.05	0.46	0.35
SFM	4'	10.36	0.85	3.45	1.66
Error	43	13.82	4.68	8.75	2.49
			Straw yield		
Rep.	3	204.34	9.45	328.50	123.03
B R	8	114.27	8.49	26.06	23.04
S	2	1251.76*	365.44*	3179.63*	1285.60*
F	2	629.54*	390.13*	1094.86*	666.04*
M	1	196.52*	85.82*	441.09*	218.00*
SF	4'	98.27	3.95	43.99	2.82
SM	2	13.90	7.59	0.81	1.93
FM	2	16.53	0.87	15.04	5.52
SFM	4'	106.13	3.10	18.34	22.82
Error	43	45.68	17.89	37.81	10.17
			Harvest Index		
Rep.	3	0.73	0.35	0.39	0.80
B R	8	0.11	0.27	0.45	0.57
S	2	0.19*	0.13*	0.23	0.47*
F	2	0.94	0.11	0.21	0.48
M	1	0.13	0.55	0.26	0.42
SF	4'	0.25	0.85*	0.11	0.55
SM	2	0.21	0.33	0.10	0.83
FM	2	0.46	0.98	0.97	0.38
SFM	4'	0.33	0.45	0.78	0.12
Error	43	0.46	0.28	0.13	0.38

APPENDIX X

Analyses of variance for nitrogen content (%) in plants.

Source	d.f.	Mean sum of squares					
		Weeks after sowing (WAS)					
		6	10	14	18	N(%)straw	N(%)grain
				1982-83			
Rep.	3	0.47	0.16	0.12	0.34	0.55	0.80
BR	8	0.19	0.39	0.17	0.85	0.21	0.21
S	2	0.33*	0.77*	0.13*	0.69*	0.23	0.98*
F	2	0.34*	0.16	0.11*	0.11*	0.21*	0.15*
M	1	0.70*	0.75*	0.10*	0.97*	0.89*	0.14*
SF	4'	0.86*	0.12*	0.34	0.50*	0.64	0.33
SM	2	0.85	0.41	0.10	0.53	0.11*	0.27
FM	2	0.11	0.19	0.29	0.22*	0.56	0.78
SFM	4'	0.19	0.43	0.51*	0.62	0.65	0.12
Error	43	0.23	0.38	0.17	0.13	0.33	0.15
				1983-84			
Rep.	3	0.64	0.70	0.30	0.11	0.32	0.20
BR	8	0.26	0.11	0.14	0.74	0.80	0.48
S	2	0.56*	0.77*	0.37*	0.74*	0.79*	0.46*
F	2	0.50*	0.22*	0.22*	0.22*	0.28*	0.55*
M	1	0.87*	0.16*	0.20*	0.14*	0.14*	0.34*
SF	4'	0.55*	0.25*	0.92	0.28*	0.33*	0.13*
SM	2	0.55	0.55	0.64	0.14	0.18	0.52
FM	2	0.46	0.48*	0.73	0.11	0.15	0.81
SFM	4'	0.10	0.11	0.29*	0.26	0.18	0.68
Error	43	0.18	0.76	0.64	0.10	0.93	0.46
				1984-85			
Rep.	3	0.36	0.20	0.53	0.52	0.45	0.18
B R	8	0.17	0.17	0.37	0.45	0.58	0.22
S	2	0.31*	0.49*	2.60*	1.64*	0.48	0.21*
F	2	0.40*	0.28*	0.82*	0.75*	0.17*	0.45*
M	1	0.17*	0.25*	0.63*	0.36*	0.37	0.15*
SF	4'	0.29	0.88*	0.73	0.89	0.72	0.81
SM	2	0.34	0.50	0.25	0.50	0.93	0.37
FM	2	0.21	0.61	0.17	0.15	0.33	0.40
SFM	4'	0.16	0.18	0.12	0.34	0.41	0.31
Error	43	0.28	0.19	0.47	0.39	0.33	0.31

APPENDIX XI

Analyses of variance for protein content(%) in grain.

Source	d.f.	Mean sum of squares 1982-83	1983-84	1984-85	Pooled
Rep.	3	0.31	7.89	0.71	1.22
B R	8	0.83	0.18	0.89	0.71
S	2	3.82*	1.83*	8.53*	4.01
F	2	5.87*	2.17*	1.81*	2.97*
M	1	5.84*	1.34*	6.17*	4.08*
SF	4	0.12*	0.50*	0.32	0.11*
SM	2	0.10	0.20	0.14	0.57
FM	2	0.30	0.31	0.18	0.29
SFM	4	0.48	0.27	0.12	0.22
Error	43	0.59	0.18	0.12	0.41

APPENDIX XII

Analyses of variance for grain protein yield kg/ha.

Source	d.f.	Mean sum of squares 1982-83	1983-84	1984-85
Rep.	3	68.0831	2249.60	22309.80
B R	8	53.38	757.61	1414.22
S	2	211.13	4594.35*	83719.70*
F	2	294.62	12203.85*	24537.05*
M	1	134.85	4445.80*	34910.90*
SF	4	37.12	2871.10*	739.55
SM	2	4.46	54.50	274.15
FM	2	2.83	73.75	4.95
SFM	4	8.99	40.99	430.05
Error	43	13.53	542.17	965.23

APPENDIX XIII

(kg/ha)

Analysis of variance for N uptake in plants.

Sources	d.f.	Mean sum of squares				
		Weeks after sowing				
		6	10	14	18	At harvest
				1982-83		
Rep.	3	0.22	0.10	18.48	5.13	411.00
B R	8	0.19	0.11	2.56	2.30	333.27
S	2	0.69*	5.39*	66.73*	395.21*	2053.97*
F	2	0.17*	1.26*	33.63*	551.15*	2221.04*
M	1	0.46*	4.69*	248.34*	640.46*	767.02*
SF	4	0.11	0.10*	3.46	24.99*	190.63
SM	2	0.17	0.43	1.36	4.35	105.46
FM	2	0.43*	0.22*	1.72	146.48*	55.92
SFM	4	0.96	0.15*	8.59*	1.23	128.77
Error	43	0.64	0.37	2.79	4.90	81.84
				1983-84		
Rep.	3	0.14	0.42	20.92	19.01	63.41
B R	8	0.11	0.10	10.68	10.49	27.43
S	2	1.12*	5.25*	155.70*	236.51*	498.17*
F	2	0.53*	3.52*	80.08*	419.97*	1063.17*
M	1	0.73*	5.89*	266.26*	394.05	368.56*
SF	4	0.18*	0.40	9.39	49.19	79.32*
SM	2	0.16	0.72	1.33	13.84	14.66
FM	2	0.11	0.84*	0.56	36.00	3.66
SFM	4	0.23*	0.19*	16.79*	4.34	3.17
Error	43	0.67	0.61	4.61	16.00	22.08
				1984-85		
Rep.	3	0.51	0.19	589.51	914.68	1174.81
B R	8	0.19	0.28	62.50	67.58	73.97
S	2	1.72*	5.91*	3699.55*	5117.85*	6474.11*
F	2	0.61*	1.98*	1307.56*	1831.88*	2319.35*
M	1	0.44*	2.48*	1371.82*	1521.22*	1970.46*
SF	4	0.27	0.79*	103.18	141.75*	143.68
SM	2	0.65*	0.36	5.79	10.81	14.74
FM	2	0.24	0.96*	22.62	14.22	8.93
SFM	4	0.21	0.52	14.30	24.00	42.42
Error	43	0.16	0.22	43.83	49.95	65.20

APPENDIX XIV

Analysis of variance for P content (%) in plants

Source	d.f.	Mean sum of squares					
		Weeks after sowing(WAS)					
		6	10	14	18	Straw	Grain
				1982-83			
Rep.	3	0.37	0.57	0.10	0.30	0.30	0.70
BR	8	0.53	0.11	0.12	0.23	0.47	0.11
S	2	0.44*	0.41*	0.21*	0.18*	0.11	0.63
F	2	0.38*	0.32*	0.22*	0.25*	0.36	0.12*
M	1	0.22*	0.15*	0.15*	0.94*	0.86	0.14*
SF	4	0.37*	0.27*	0.25	0.10	0.28	0.24
SM	2	0.10	0.78	0.27	0.15	0.70	0.13
FM	2	0.31*	0.29	0.56	0.67	0.38	0.53
SFM	4	0.11	0.14	0.20	0.14	0.73	0.45
Error	43	0.60	0.73	0.12	0.10	0.16	0.21
				1983-84			
Rep.	3	0.28	0.55	0.95	0.10	0.26	0.54
BR	8	0.18	0.27	0.60	0.11	0.68	0.29
S	2	0.90*	0.22*	0.30*	0.20*	0.50	0.83*
F	2	0.30*	0.48*	0.21*	0.29*	0.73*	0.28
M	1	0.21*	0.20*	0.98*	0.14*	0.28*	0.53
SF	4	0.36	0.22	0.11*	0.26	0.12*	0.37
SM	2	0.54	0.55	0.12	0.27	0.50	0.42
FM	2	0.75	0.55	0.96	0.65	0.67	0.96
SFM	4	0.12	0.50	0.49	0.15	0.14	0.31
Error	43	0.24	0.13	0.94	0.11	0.76	0.21
				1984-85			
Rep.	3	0.17	0.16	0.13	0.97	0.19	0.49
BR	8	0.13	0.37	0.20	0.92	0.37	0.27
S	2	0.50*	0.33*	0.31*	0.27*	0.10	0.62*
F	2	0.43*	0.46*	0.70*	0.98*	0.14*	0.37*
M	1	0.14*	0.14*	0.37*	0.16*	0.30	0.20
SF	4	0.32*	0.50*	0.76*	0.40*	0.57*	0.36
SM	2	0.38	0.12	0.18	0.11	0.63	0.12
FM	2	0.13	0.13	0.28	0.18	0.38	0.22
SFM	4	0.46	0.17	0.36*	0.63	0.22	0.16
Error	43	0.96	0.12	0.10	0.10	0.20	0.62

APPENDIX XV

Analysis of variance for P uptake (kg/ha) in plants.

Sources	d.f.	Mean sum of squares				
		Weeks after sowing				
		6	10	14	18	At harvest
				1982-83		
Rep.	3	0.69	0.12	0.18	0.78	1.81
B R	8	0.14	0.14	0.16	0.64	1.73
S	2	0.36*	0.98*	5.54*	9.84*	11.83*
F	2	0.31*	0.54*	4.03*	12.28*	14.83*
M	1	0.40*	0.59*	4.38*	0.06*	5.02*
SF	4	0.26	0.10	0.28	0.27	1.05
SM	2	0.49	0.27	0.37	0.52	0.21
FM	2	0.41*	0.15	0.52	0.28	0.36
SFM	4	0.92	0.19*	0.26	0.51	0.66
Error	43	0.39	0.60	0.17	0.24	0.63
				1983-84		
Rep.	3	0.77	0.20	0.60	0.15	0.54
B R	8	0.35	0.17	0.38	0.12	0.80
S	2	0.41*	0.53*	5.86*	5.93*	9.33*
F	2	0.28*	0.48*	3.29*	5.61*	9.80*
M	1	0.50*	0.48*	1.86*	4.55*	5.94*
SF	4	0.11	0.11	0.48*	0.42	0.36
SM	2	0.29	0.26	0.60	0.26	0.43
FM	2	0.28*	0.19*	0.21*	0.57	0.38
SFM	4	0.64	0.61	0.81	0.27	0.61*
Error	43	0.61	0.58	0.49	0.16	0.23
				1984-85		
Rep.	3	0.49	0.10	0.48	0.18	0.22
B R	8	0.59	0.11	0.19	0.16	0.18
S	2	0.56*	0.89	8.30*	10.02*	10.69*
F	2	0.43*	0.37	2.41*	2.76*	2.92*
M	1	0.27*	0.22	7.50*	6.32*	6.84*
SF	4	0.11	0.98	0.79*	0.83*	0.83*
SM	2	0.35	0.11	0.33	0.10	0.95
FM	2	0.86	0.14	0.49*	0.26	0.19
SFM	4	0.99	0.14	0.21	0.20	0.19
Error	43	0.64	0.12	0.15	0.29	0.31

APPENDIX XVI

Analysis of variance for K content per cent in plants.

Sources	d.f.	Mean sum of squares					
		Weeks after sowing					
		6	10	14	18	Straw	Grain
				1982-83			
Rep.	3	0.15	0.19	0.89	0.64	0.70	0.82
B R	8	0.16	0.30	0.43	0.58	0.53	0.54
S	2	0.11*	0.52*	1.03*	0.98*	0.11	0.20
F	2	2.70*	4.48*	1.54*	0.63*	0.16*	0.12*
M	1	0.74*	0.43*	0.29*	0.73	0.31	0.73*
SF	4	0.25	0.13	0.28	0.30	0.19	0.38
SM	2	0.72	0.13	0.51	0.40	0.52	0.55
FM	2	0.41	0.21	0.31	0.55	0.79	0.22
SFM	4	0.43	0.38	0.40	0.23	0.17	0.76
Error	43	0.33	0.58	0.42	0.40	0.37	0.68
				1983-84			
Rep.	3	0.13	0.32	0.16	0.20	0.18	0.23
B R	8	0.51	0.13	0.65	0.47	0.45	0.34
S	2	0.14	0.21	0.70*	0.51*	0.73*	0.15
F	2	4.66	4.26	0.78*	1.06*	0.19*	0.47*
M	1	0.36	0.64	0.70*	0.30*	0.37*	0.61*
SF	4	0.22	0.56	0.76	0.76	0.32	0.26
SM	2	0.45	0.28	0.28	0.91	0.17	0.12
FM	2	0.11	0.15	0.13	0.29	0.41	0.41
SFM	4	0.44	0.85	0.63	0.21	0.83	0.41
Error	43	0.30	0.40	0.62	0.48	0.18	0.77
				1984-85			
Rep.	3	0.11	0.10	0.25	0.35	0.80	0.23
B R	8	0.11	0.21	0.36	0.67	0.17	0.13
S	2	0.62*	0.45	3.87*	3.05*	0.23	0.84
F	2	2.44*	3.93*	2.51*	2.07*	0.32*	0.11*
M	1	0.30*	0.91*	0.82*	0.48*	0.67	0.22
SF	4	0.95	0.32	0.77	0.36	0.72*	0.76
SM	2	0.14	0.87	0.15	0.93	0.26	0.51
FM	2	0.18	0.11	0.35	0.17	0.21	0.10
SFM	4	0.62	0.25	0.41	0.30	0.60	0.11
Error	43	0.62	0.50	0.94	0.99	0.26	0.68

APPENDIX XVII

Analysis of variance for K uptake (kg/ha) in plants.

Sources	d.f.	Mean sum of squares				
		Weeks after sowing				
		6	10	14	18	At harvest
				1982-83		
Rep.	3	0.28	0.89	118.32	214.96	212.56
B R	8	0.52	0.24	39.75	176.34	145.75
S	2	0.80*	18.21*	1842.58*	4669.86*	4442.31*
F	2	1.53*	42.60*	2170.30*	2633.11*	2997.14*
M	1	1.06*	18.46*	516.01*	1057.29*	1023.93*
SF	4	0.16	0.29	50.05	54.42	76.30
SM	2	0.77	0.11	9.18	200.63	145.20
FM	2	0.87*	1.08	13.60	59.56	45.48
SFM	4	0.20	0.30	78.19	53.78	52.22
Error	43	0.11	0.38	62.15	118.09	110.56
				1983-84		
Rep.	3	0.26	0.21	96.99	50.26	42.03
B R	8	0.17	0.13	29.64	88.21	73.08
S	2	0.95*	8.43*	1087.49*	1347.67*	1687.01*
F	2	1.85*	29.84*	987.49*	1948.26*	2315.41*
M	1	1.18*	15.82*	863.68*	945.18*	1035.81*
SF	4	0.23	0.38*	27.39	8.06	13.19
SM	2	0.57	0.26	32.04	78.31	58.90
FM	2	0.35	0.76*	21.08	42.58	21.76
SFM	4	0.33	0.43*	14.14	46.79	33.90
Error	43	0.11	0.14	44.67	70.75	72.84
				1984-85		
Rep.	3	0.11	0.77	304.62	1003.15	1111.46
B R	8	0.39	0.32	44.03	94.73	96.62
S	2	2.10*	12.39*	6003.06*	9130.99*	9410.21*
F	2	1.73*	37.20*	3784.40*	5674.38*	5802.40*
M	1	0.69*	19.45*	1612.73*	2198.95*	2329.72*
SF	4	0.36	0.33	111.26	36.66	57.34
SM	2	0.10	0.20	24.72	14.40	3.84
FM	2	0.74	0.53	147.05	179.40	178.63
SFM	4	0.31	0.11	77.42	63.52	74.14
Error	43	0.32	0.33	84.62	146.20	148.37

APPENDIX XVIII

Analysis of variance for soil moisture content (%) in 0-15cm soil depth.

Sources	d.f.	Mean sum of squares					
		I	II	III	IV	V	At harvest
				1982-83			
Rep.	3	2.33	4.56	10.88	6.69	4.86	9.75
B R	8	1.99	8.88	2.24	2.88	1.77	1.09
S	2	46.81*	31.98*	14.69*	7.02*	2.53	8.67*
F	2	17.72*	58.51*	26.78*	12.19*	17.08*	50.05*
M	1	23.62*	60.84*	38.66*	58.31*	51.83*	37.87*
SF	4	4.36	67.61*	3.02	2.21	0.66	6.46*
SM	2	0.21	4.07	0.17	9.93*	0.76	0.53
FM	2	1.05	0.79	0.12	0.58	2.07	2.03
SFM	4	3.25	12.42*	1.54	1.29	0.25	1.46
Error	43	2.25	2.43	2.30	2.15	2.16	1.90
				1983-84			
Rep.	3	8.48	25.82	7.51	11.03	15.84	9.20
B R	8	4.79	3.32	3.77	1.88	0.80	4.93
S	2	5.44*	26.98*	76.80*	32.12*	15.03*	5.05
F	2	72.79*	26.39*	42.29*	17.59*	0.14	7.59*
M	1	58.71*	53.28*	73.60*	49.66*	73.20*	60.90*
SF	4	18.35*	7.14	3.73	1.99	6.87*	17.89*
SM	2	0.68	0.37	0.37	0.60	3.31*	0.53
FM	2	3.13	0.18	0.28	1.03	1.98	3.20
SFM	4	0.75	1.81	1.31	0.98	1.23	0.68
Error	43	1.64	2.76	4.44	4.12	0.68	1.64
				1984-85			
Rep.	3	3.39	7.89	0.89	9.61	18.77	17.34
B R	8	0.52	1.78	2.34	9.88	1.29	2.29
S	2	22.47*	2.45	22.73*	1.75	10.68*	16.24*
F	2	9.60	14.12*	24.46*	25.68*	15.08*	10.28*
M	1	60.04*	70.56*	46.22*	55.55*	29.05*	18.74*
SF	4	22.90*	5.47	14.72*	117.68*	2.99*	6.22*
SM	2	1.16	1.14	0.57	0.34	0.16	0.88
FM	2	2.35	0.12	0.26	0.53	0.14	0.41
SFM	4	3.80	2.33	0.60	1.45	0.11	0.96
Error	43	3.85	2.93	2.41	4.32	0.99	1.92

APPENDIX XIX

Analysis of variance for physico-chemical properties of soil.

Sources	d.f.	Mean sum of squares					
		Bulk density	Available N	Available P	Available K	Total N	Organic carbon
				1982-83			
Rep.	3	0.53	198.00	11.50	93.66	13774.00	0.39
B R	8	0.11	684.00	31.22	483.30	13623.37	0.10
S	2	0.19	15.00	67.59*	234.50	173075.00*	0.48
F	2	0.55*	5924.50*	168.43*	1461.35*	46814.50*	0.20*
M	1	0.82*	2255.00	46.72	3186.60*	239056.00*	0.10
SF	4	0.40	618.00	11.08	1007.25	41615.00*	0.94*
SM	2	0.84	58.00	5.09	62.90	5477.00	0.10*
FM	2	0.20	356.00	76.01*	1619.50*	1976.00	0.36*
SFM	4	0.50	910.45	13.66	650.89	6216.95	0.71
Error	43	0.26	1339.21	11.63	439.62	3296.74	0.59
				1983-84			
Rep.	3	0.12	1689.66	12.19	363.10	88496.66	0.52
B R	8	0.14	1193.50	5.84	1413.36	1438.25	0.37
S	2	0.11	434.50	45.54*	162.40	70015.00*	0.76
F	2	0.43*	4441.50	149.62*	1657.10	168865.00*	0.44*
M	1	0.26*	1466.00	74.01*	1624.50	115015.00*	0.12*
SF	4	0.56	504.00	19.69*	77.25	10117.50*	0.14
SM	2	0.16	160.50	35.09*	39.50	34028.00*	0.18
FM	2	0.41	201.50	15.26	586.15	2912.50	0.20
SFM	4	0.38	1555.23	3.13	625.21	445.17	0.69
Error	43	0.37	2187.86	6.72	1033.63	2867.10	0.73
				1984-85			
Rep.	3	0.20	1332.00	42.40	238.03	40529.00	0.28
B R	8	0.22	365.50	48.55	1613.35	2540.62	0.16
S	2	0.20	817.00	6.75	763.80	87993.00*	0.53
F	2	0.49*	3686.00	3.97	1481.80	142032.50*	0.60*
M	1	0.39*	7442.00*	0.22	105.00	243084.00*	0.40*
SF	4	0.28	701.00	49.28	81.25	1297.50	0.15
SM	2	0.34	212.00	214.01*	341.35	29801.50*	0.97
FM	2	0.24	547.00	100.93	109.10	5529.00	0.32
SFM	4	0.55*	1099.73	35.60	985.15	1240.43	0.45
Error	43	0.21	1654.67	63.63	989.50	3361.26	0.22

APPENDIX XX

Effect of S x F interaction on growth characters.

Characters	S_1F_1	S_1F_2	S_1F_3	S_2F_1	S_2F_2	S_2F_3	S_3F_1	S_3F_2	S_3F_3	SEm±	CD5%
Plant height(cm)											
12WAS 1983-84	40.8	36.7	37.0	37.1	39.8	38.0	33.0	33.1	38.8	0.9	2.8
15WAS 1983-84	46.9	50.9	52.4	46.9	48.7	48.0	41.0	45.6	50.8	0.8	2.3
Harvest 1984-85	58.3	56.7	61.2	52.0	60.5	57.7	53.9	53.7	57.4	1.2	3.7
Dry matter accumulation (g/m^2)											
6 WAS 1983-84	2.9	3.5	3.9	4.2	4.3	4.9	4.3	5.1	5.0	0.1	0.3
18WAS 1982-83	487.3	496.2	511.5	510.1	526.3	530.4	518.8	538.5	568.2	4.3	12.3
Per cent dry matter accumulation(g/m^2)											
10 WAS 1982-83	4.91	5.04	5.06	5.08	5.04	5.08	5.04	5.03	5.11	0.02	0.07
18WAS 1984-85	43.9	44.5	44.4	44.5	44.5	44.5	44.4	44.6	44.8	0.1	0.3
Harvest 1984-85	56.8	57.4	58.0	58.1	58.0	58.4	57.9	59.0	58.9	0.1	0.3
Days to 100% heading											
1983-84	112.0	108.1	105.2	110.6	108.0	112.5	111.0	112.5	107.2	1.0	2.8
Number of grains/spike											
1982-83	32.1	34.7	33.4	31.6	29.8	31.9	29.7	29.9	32.7	0.7	2.0
Number of grains/spike											
1983-84	25.9	25.1	26.9	22.0	27.0	26.7	24.9	23.5	23.9	0.7	2.0
1984-85	29.5	31.0	31.1	27.4	29.0	32.7	29.7	27.7	30.9	0.5	1.4
1000-grain weight(g)											
1982-83	39.3	29.1	41.3	39.5	38.8	39.8	37.5	40.1	40.0	0.4	1.2
1984-85	46.2	47.0	46.5	44.4	44.5	50.0	45.3	47.4	44.4	1.0	3.0
Harvest index											
1983-84	0.32	0.33	0.31	0.33	0.31	0.32	0.33	0.29	0.29	0.01	0.04

APPENDIX XXI

Effect of S x F interaction on nutrient content and uptake in plants and available nutrient in soil after harvest

Characters	S_1F_1	S_1F_2	S_1F_3	S_2F_1	S_2F_2	S_2F_3	S_3F_1	S_3F_2	S_3F_3	SEm±	CD 5%
N content in plants											
Straw 1983-84	0.53	0.59	0.60	0.54	0.52	0.58	0.53	0.58	0.62	0.01	0.03
Grain 1983-84	1.52	1.55	1.61	1.57	1.56	1.59	1.56	1.63	1.76	0.02	0.07
Protein content in grains											
1982-83	8.7	9.3	9.9	9.2	9.9	10.5	9.6	10.2	10.6	0.09	0.2
1983-84	9.5	9.7	10.1	9.8	9.8	9.9	9.7	10.1	11.0	0.2	0.5
N uptake in plant (kg/ha)											
6WAS 1983-84	0.65	0.84	0.94	0.95	0.98	1.22	1.04	1.26	1.41	0.03	0.09
Harvest 1983-84	23.0	27.4	34.1	26.8	35.3	35.8	26.5	39.4	46.7	1.9	5.4
P content in plants											
18WAS 1984-85	0.067	0.083	0.097	0.093	0.095	0.099	0.103	0.101	0.103	0.004	0.012
P uptake in plant (kg/ha)											
18WAS 1984-85	2.8	3.7	4.3	4.3	4.4	4.7	4.8	4.8	5.0	0.2	0.6
Harvest 1984-85	2.9	3.8	4.4	4.4	4.5	4.8	4.9	4.9	5.2	0.2	0.6
Soil moisture content during 2nd observation											
1982-83	23.1	25.0	26.6	23.9	23.1	23.2	21.2	23.0	24.1	0.6	1.9
Available soil P											
1983-84	18.9	21.4	25.5	19.9	20.6	20.7	15.1	20.4	21.4	1.0	3.0
Soil organic carbon content											
1982-83	0.56	0.62	0.85	0.53	0.66	0.77	0.64	0.71	0.60	0.03	0.08

APPENDIX XXII

Effect of S x M interaction on growth, yield characters, nutrient content and uptake in plants and soil organic carbon content after harvest.

Characters	S_1M_1	S_1M_2	S_2M_1	S_2M_2	S_3M_1	S_3M_2	SEm±	CD5%
Days taken to complete germination								
1983-84	26.5	25.0	26.3	24.5	26.0	23.1	0.2	0.7
Number of shoots								
8 WAS 1984-85	77.1	77.2	80.5	77.9	78.0	91.3	1.5	4.3
10WAS 1984-85	92.9	90.4	98.2	91.9	89.6	104.6	1.3	3.7
Plant height (cm)								
6 WAS 1982-83	8.2	8.8	8.6	8.3	8.0	8.4	0.1	0.4
9 WAS 1983-84	13.0	12.3	11.8	13.0	11.5	10.9	0.3	0.8
12WAS 1983-84	37.2	39.8	36.8	39.6	35.0	34.3	0.6	1.9
Harvest 1984-85	55.8	61.3	54.9	58.4	55.7	56.2	0.9	2.6
Dry matter accumulation (g/m^2)								
6 WAS 1983-84	3.0	3.9	4.2	4.7	4.5	5.0	0.08	0.23
18WAS 1983-84	354.4	387.3	388.3	401.6	399.4	404.8	2.3	6.6
Harvest 1983-84	338.3	387.1	414.7	435.1	420.6	437.5	6.2	17.6
Per cent dry matter accumulation								
14 WAS	37.3	37.5	37.3	37.9	37.4	37.9	0.08	0.2
Harvest	56.9	57.9	57.8	56.6	58.5	58.5	0.08	0.02
100 per cent heading								
1983-84	105.9	111.4	109.0	111.1	111.7	109.0	0.7	2.0
No.of grains per spike								
1983-84	23.5	28.0	25.6	25.3	23.2	25.0	0.5	1.4
1984-85	29.2	32.2	29.0	30.3	28.9	29.7	0.3	1.0
N content in plants								
1982-83	0.53	0.52	0.55	0.52	0.52	0.57	0.01	0.04
Protein yield (kg/ha)								
1983-84	100.7	115.4	117.6	131.0	126.0	145.1	6.7	19.0
N uptake (kg/ha)								
6 WAS 1984-85	0.9	1.2	1.3	1.4	1.5	1.7	0.03	0.1
Soil organic carbon content								
1982-83	0.68	0.68	0.71	0.59	0.58	0.72	0.02	0.06

APPENDIX XXIII

Effect of F x M interaction on growth and yield characters.

Characters	F_1M_1	F_1M_2	F_2M_1	F_2M_2	F_3M_1	F_3M_2	SEm$\pm$	CD5%
Number of shoots m^{-1} row length								
12 WAS 1982-83	94.6	91.6	94.8	104.5	95.3	111.0	1.4	4.1
8 WAS 1983-84	61.0	62.5	69.0	68.2	66.1	79.7	1.3	3.9
Green matter accumulation (g/m^2)								
6 WAS 1982-83	25.4	25.1	25.5	27.3	25.9	28.4	0.3	1.0
14WAS 1984-85	793.8	782.8	789.6	834.8	806.1	860.9	13.5	38.3
Dry matter accumulation (g/m^2)								
6 WAS 1982-83	5.0	5.2	5.1	5.6	5.3	6.1	0.08	0.2
Per cent dry matter accumulation								
6 WAS 1982-83	4.47	4.62	4.54	4.57	4.55	4.68	0.02	0.05
18WAS 1983-84	42.2	42.4	42.3	43.0	42.3	42.9	0.05	0.15
Harvest 1984-85	57.5	57.6	57.7	58.5	58.1	58.8	0.08	0.2
Days to heading								
50% heading 1983-84	100.0	99.8	99.9	97.7	94.7	97.6	0.8	2.2
100% heading 1983-84	109.5	112.4	107.2	112.2	109.9	106.9	0.7	2.0
Number of grains/spike								
1983-84	23.6	25.0	24.7	25.8	24.0	27.5	0.5	1.5
1000-grain weight(g)								
1982-83	38.8	38.9	38.4	40.3	39.6	41.0	0.3	0.9
1984-85	44.4	46.0	45.3	47.0	48.6	46.0	0.7	2.1

APPENDIX XXIV

Effect of F x M interaction on nutrient content, uptake in plants and available soil P,K and organic carbon content after harvest.

Characters	F_1M_1	F_1M_2	F_2M_1	F_2M_2	F_3M_1	F_3M_2	SEm±	CD5%
N content in plants								
10 WAS 1983-84	1.43	1.43	1.49	1.67	1.55	1.66	0.02	0.07
18 WAS 1982-83	0.55	0.59	0.59	0.63	0.64	0.78	0.01	0.03
N-uptake in plant(kg/ha)								
6 WAS 1982-83	1.16	1.25	1.22	1.36	1.24	1.50	0.02	0.06
18 WAS 1982-8	28.0	30.3	30.0	34.0	37.2	44.3	0.6	1.8
P content in plant(%)								
6 WAS 1982-83	0.147	0.150	0.151	0.167	0.167	0.180	0.002	0.006
P uptake in plant (kg/ha)								
10 WAS 1983-84	0.19	0.22	0.22	0.29	0.26	0.33	0.007	0.02
K uptake in plant (kg/ha)								
6 WAS 1982-83	1.00	1.11	1.15	1.41	1.38	1.74	0.03	0.08
10WAS 1983-84	3.2	3.8	3.8	5.1	5.3	6.2	0.1	0.3
Soil available nutrient after harvest								
P 1982-83	20.5	18.0	20.2	23.1	22.4	26.7	0.9	2.7
K 1982-83	200.9	202.0	186.2	218.2	212.0	218.7	6.0	17.1
Organic carbon content (%)								
1982-83	0.53	0.59	0.66	0.70	0.78	0.70	0.02	0.06

APPENDIX XXV

Effect of S x F x M interaction on growth and development characters.

SxFxM	Number of shoot m^{-1} row length 8 WAS 1984-85	Plant height (cm) 6 WAS 1982-83	Plant height (cm) 9 WAS 1983-84	Plant height (cm) Harvest 1984-85	Green matter accumulation (g/m^2) 18 WAS 1982-83	Green matter accumulation (g/m^2) Harvest 1983-84	Dry matter accumulation (g/m^2) 18 WAS 1982-83	Per cent dry matter accumulation 10WAS 1982-83	Per cent dry matter accumulation Harvest 1984-85	Days to heading 50 % 1983-84	Days to heading 100% 1983-84
$S_1F_1M_1$	73.7	8.5	14.4	58.2	1046.1	428.1	479.0	4.79	56.5	97.5	111.7
$S_1F_1M_2$	81.0	8.4	12.4	58.0	1036.5	442.9	491.4	5.03	57.0	99.2	112.2
$S_1F_2M_1$	65.7	8.3	12.8	49.6	1016.6	428.3	478.5	5.02	56.7	100.0	106.5
$S_1F_2M_2$	77.5	8.7	12.2	63.5	1080.0	500.7	513.3	5.07	58.0	95.5	110.5
$S_1F_3M_1$	92.0	8.1	11.8	59.6	1024.6	438.7	487.5	5.06	57.5	91.0	99.5
$S_1F_3M_2$	77.2	9.5	12.2	62.1	1130.0	528.8	535.3	5.06	58.5	99.0	111.5
$S_2F_1M_1$	69.5	8.1	10.4	48.5	1084.8	500.9	510.8	5.08	57.7	101.2	107.7
$S_2F_1M_2$	65.0	8.2	12.0	57.3	1072.9	499.7	507.7	5.06	58.5	99.7	112.2
$S_2F_2M_1$	83.7	8.9	11.8	59.1	1085.7	484.9	505.9	5.02	56.6	101.0	102.2
$S_2F_2M_2$	82.0	8.4	14.8	61.8	1130.2	557.0	548.7	5.06	58.5	96.8	113.5
$S_2F_3M_1$	88.5	8.8	13.0	57.0	1072.9	555.7	512.0	5.03	58.1	91.5	117.0
$S_2F_3M_2$	86.7	9.4	12.2	57.9	1126.3	551.4	551.4	5.11	58.6	98.7	107.5
$S_3F_1M_1$	79.0	8.2	10.3	53.9	1087.6	509.6	509.9	5.03	58.3	101.2	109.0
$S_3F_1M_2$	89.5	8.3	9.1	54.8	1111.3	500.9	532.6	5.04	57.3	100.5	112.7
$S_3F_2M_1$	74.7	7.6	11.1	54.1	1131.1	515.3	532.6	5.04	58.7	98.7	113.0
$S_3F_2M_2$	85.2	8.5	10.3	58.0	1112.1	542.2	546.7	5.05	59.0	100.7	112.5
$S_3F_3M_1$	80.2	8.1	13.2	59.3	1129.0	540.5	535.9	5.04	58.6	101.5	113.0
$S_3F_3M_2$	99.2	9.6	13.0	55.9	1194.4	555.9	603.0	5.19	59.1	95.2	101.7
SEm±	3.3	0.3	0.6	2.0	16.3	2.3	6.7	0.38	0.5	1.7	1.5
C.D.5%	9.2	0.9	1.7	5.6	45.2	6.4	18.6	1.07	1.5	4.9	4.3

APPENDIX XXVI

Effect of S x F x M interaction on yield characters, nutrient content, uptake in plants soil moisture content and bulk density after harvest

S x F x M	No.of effective tillers m^{-2} row length	No.of grains/spike		1000-grain weight		N uptake in plant (kg/ha) 6 WAS	P content in plant (%) 14 WAS	P uptake (kg/ha) in plant Harvest	K-uptake (kg/ha) 10 WAS	Soil moisture content during 2nd observation	Bulk density at harvest
	1983-84	1983-84	1984-85	1982-83	1984-85	1983-84	1984-85	1983-84	1983-84	1982-83	1984-85
$S_1F_1M_1$	39.8	24.4	26.6	38.9	45.9	0.5	0.075	2.50	2.3	23.5	1.335
$S_1F_1M_2$	50.2	27.1	29.6	40.1	46.3	0.7	0.097	2.58	3.1	25.5	1.310
$S_1F_2M_1$	54.7	24.9	30.0	38.3	46.2	0.7	0.110	2.76	3.2	19.6	1.325
$S_1F_2M_2$	55.5	25.0	32.7	40.2	47.6	0.9	0.111	2.84	4.7	24.2	1.300
$S_1F_3M_1$	53.8	21.4	28.0	40.6	46.6	0.8	0.095	3.35	4.9	28.1	1.315
$S_1F_3M_2$	49.0	31.9	34.3	42.2	47.1	1.0	0.128	4.01	5.1	30.0	1.295
$S_2F_1M_1$	42.0	22.0	27.0	38.9	42.7	0.8	0.102	2.77	3.6	22.1	1.330
$S_2F_1M_2$	55.5	22.5	27.5	40.3	45.9	1.0	0.125	3.85	3.7	25.4	1.337
$S_2F_2M_1$	62.7	29.1	28.5	38.4	43.4	0.8	0.112	3.72	3.9	22.9	1.322
$S_2F_2M_2$	51.2	25.4	29.8	39.8	45.2	1.6	0.117	4.15	5.1	20.4	1.302
$S_2F_3M_1$	54.0	25.9	31.6	39.4	55.1	1.0	0.102	3.90	5.6	23.0	1.310
$S_2F_3M_2$	58.2	28.1	33 5	40.1	45.4	1.3	0.120	4.76	6.6	26.0	1.295
$S_3F_1M_1$	48.0	24.5	28.0	38.7	44.7	1.0	0.117	3.16	3.8	19.2	1.342
$S_3F_1M_2$	49.0	25.3	30.9	36.4	45.7	1.0	0.132	3.66	4.6	19.7	1.332
$S_3F_2M_1$	50.2	20.2	26.0	38.5	46.5	1.1	0.110	3.58	4.2	24.5	1.317
$S_3F_2M_2$	62.0	27.1	29.7	41.6	48.1	1.4	0.123	4.80	5.4	28.3	1.322
$S_3F_3M_1$	64.5	25.0	32.9	38.8	44.1	1.3	0.126	4.93	5.4	22.1	1.317
$S_3F_3M_2$	65.0	22.7	28.6	40.7	45.4	1.4	0.135	5.21	6.9	23.3	1.285
SEm±	1.9	1.1	0.7	0.6	1.6	0.5	0.065	0.04	0.2	0.9	0.002
CD5%	5.5	3.1	2.1	1.8	4.6	1.4	0.182	0.13	0.6	2.7	0.008