RESPONSE OF POTATO TO NITROGEN AS INFLUENCED BY IRRIGATION AND ORGANIC MATTER

THESIS

By

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Dedicated

to my Father

Late Shri Laxmi Prasad Shrestha

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Palampur,
Dated 29th July, 1987

(Ananda Prasad Shrestha)

CERTIFICATE - I

Certified that the thesis entitled "Response of Potato to nitrogen as influenced by irrigation and organic matter", submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy (Agriculture) in the subject of Soil Science and Water Management of Himachal Pradesh Krishi Vishva Vidyalaya, Palampur, is the bonafide research work carried out by Shri Ananda Prasad Shrestha, son of Shri Laxmi Prasad Shrestha, 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 fully acknowledged.

29.7.

(Dr.R.S.Minhas)
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CERTIFICATE - II

This is to certify that the thesis entitled "Response of potato to nitrogen as influenced by irrigation and organice matter", submitted by Mr. Ananda Prasad Shrestha, son of Shri Laxmi Prasad Shrestha, to the Himachal Pradesh Krishi Vishva Vidyalaya, Palampur in partial fulfilment of the requirements for the degree of Doctor of Philosophy (Agriculture) in the subject of Soil Sciences & Water Management, has been approved by the student's advisory committee after an oral examination of the same in collaboration with an External Examiner.

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INTRODUCTION

INTRODUCTION

Potato is a potential crop for solving World's food problem. It was introduced in India by the beginning of 17th century. It is one of the most important cash crops of Himachal Pradesh, occupying an area of 12.6 thousand hectares. The average yield of potato in the Pradesh is only 32 q/ha as against the national average of 131.13 quintal/ha (Anonymous,1982).The reasons ascribed for low yields could be low and imbalanced use of chemical fertilizers and lack of irrigation facilities to which potato is reported to respond very high in different regions of the country (Singh et al., 1961; Grewal and Sharma, 1978; Sharma and Grewal, 1978; Bhattacharjee et al., 1979; Sharma et al., 1980; Grewal and Sharma, 1980; Grewal et al.,1981; Singh and Sharma, 1983; Singh and Grewal, 1983; Trehan and Grewal, 1984).

Among the major nutrients, nitrogen is the first limiting nutrient for the production of potato as the needs of the crop are very high due to production of large foliage in a short period. In the event of its deficiency, lower leaves of the plant become yellow and later the whole of the plant gives yellowish appearance and the growth of the plant is stunted. Nitrogen application increases the plant growth and leaf area. It increases the tuber number as well as the tuber size.Potato grown on the acid soils of Himachal Pradesh responds to nitrogen heavily (Sharma et al., 1975; Grewal et al.,1979; Sharma, 1986) as most of the soils are not able to supply the required quantity of this nutrient. Therefore, the application of nitrogenous fertilisers in ours soils becomes necessary to meet the nitrogen needs of the crop for obtaining optimum yields.

On the other hand the ever increasing cost of crude oil world over is making chemical fertilizers, especially nitrogen, a costly input. The low fertilizer nitrogen use efficiency, which seldom exceeds 40-50 per cent, also gives farmers low returns (Sharma et al., 1984). Hence, the judicious use of fertilizer-N is a must to reduce the cost of production.

The high cost and low agronomic effectiveness of nitrogenous fertilizers call for alternative sources of nitrogen and measures that could enhance the fertilizer recovery. The incorporation of organic manures along with fertilizer nitrogen enhances the fertilizer nitrogen use efficiency by releasing it slowly in the soil, besides serving itself as a source of nitrogen to plants (Sharma et al., 1980; Sahota et al., 1984). The positive association of organic manure and nitrogen has been reported by Dimitrov (1964), Below (1968), Shloma (1968) and Singh(1975). The addition of organic manures also improves the physical environment of soil, which is so important for the proper proliferation of roots and tuberization. The incorporation of organic manure also improves the water use efficiency of the crop.

One of the readily available sources of organic matter on farm is FYM. But under intensive cultivation, it also becomes scarce and farmers have to look for other sources of organic matter (Biswas, 1982). There is a growing concern of researchers planners and social reformers about the spread of obnoxious weed viz. Lantana camara, which is posing a great threat to out agricultural sector by replacing grasses and other desirable vegetation from pastures, forests and wastelands. It would be quite heartening to know if it could be recycled in the form of an organic manure and serve as a source of nutrition to plants.

There are still apprehensions as to the beneficial effects of the addition of Lantana camara to soils as it contains alkaloids (Joshi and Magar, 1952; Barton et al., 1954; Nigam et al., 1957; Sharma et al., 1980; Wadhwani and Bhardwaj, 1981; Sharma, 1984; Acchireddy and Singh, 1984; Acchireddy et al., 1985 and Singh and Saxena, 1987) which could prove toxic to plants. However, these alkaloids could act as nitrification inhibitors and enhance nitrogen use efficiency.

The amount of water available to the potato plant is quite critical during its active growth phase which can effect the size and number of tubers as well as their quality (Prince & Blood, 1962). Potato being a short duration crop bulks up rapidly and due to its sparse and shallow root system nearly 70 per cent of the total water supply comes from the upper 30 cm layer. Therefore, the deeper layers do not contribute materially to the water supply of the crop (Singh et al., 1968). Irrigation and N application are the most important factors contributing to the growth and yield of potato (Singh and Grewal, 1983). But the potato crop grown for seed at higher altitudes

1600 m. above mean sea level in Himachal Pradesh is rainfed. However, under mid and low hill conditions potato grown for table purpose is mostly irrigated. It would, therefore, be worthwhile to see the effect of irrigation alone as well as in combination with N and organic materials on the vegetative growth, tuber size and yield of potato in the mid hills of the State.

Therefore, considering the significance of the above problems, a research study entitled, " Response of Potato to nitrogen as influenced by irrigation and organic matter", was envisaged with the following objectives:

(i) To find out a suitable nitrogen dose for potato under mid hill conditions of Himachal Pradesh.

(ii) To find out the effect of FYM application in combination with N on soil properties as well as growth and yield of potato and to see the feasibility of its substitution by plant material like *Lantana camara*.

(iii) To see the effect of optimum irrigation on potato growth and development as compared to rainfed conditions.

(iv) To study the effect of N, FYM, *Lantana camara* and irrigation on the quality of potato.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Potato responds quite high to the application of nitrogen and irrigation. Also the incorporation of organic matter along with fertilizer nitrogen plays an important role in enhancing fertilizer use efficiency, besides favourably affecting the physical environment of the soil (Biswas and Oza, 1978). The optimum soil physical conditions will enhance water use, root proliferation, nutrient uptake, tuberization and other metabolic processes associated with good physical environment. A fairly good amount of fertilizer nitrogen could be substituted by organic manures when applied in conjunction with fertilizer nitrogen (Meelu and Singh, 1978). The pertinent literature concerning all these aspects has been reviewed under the following heads and sub-heads:

2.1 Effect of organic manure and nitrogen on forms of nitrogen in the soil.

2.1.1 Effect of organic manure and nitrogen on NO_3-N.

2.1.2 Effect of organic manure and nitrogen on NH_4-N.

2.2 Effect of organic manure and nitrogen on organic carbon.

2.3 Effect of nitrogen and organic matter on vegetative growth of potato.

2.4 Effect of different treatments on tuber yield and tuber size of potato.

2.4.1 Effect of nitrogen and organic matter on tuber yield and tuber size of potato.

2.4.1.1 Effect of nitrogen

2.4.1.2 Effect of organic manure.

2.1 Effect of organic manure and nitrogen on forms of nitrogen in the soil.

Nitrogen in soils is present in different forms which are continuously undergoing transformation. Larger fraction of nitrogen is, however, present in organic form which is not readily available to plants. Depending on soil environment this form gets transformed to the inorganic form to be available to plants. Plants differ in their capacity for uptake and assimilation of NH_4-N and NO_3-N (Barker and Mills, 1980) and potatoes preferentially take up NO_3-N over NH_4-N (Roberts and Cheng,1984). Results of various studies on the use of organic matter and inorganic fertilizers have been reviewed as follows:

2.1.1 Effect of organic manure and nitrogen on NO_3-N.

Gawronska-Kulesza (1966) observed that the effect of manure on NO_3-N was small and was dependent on the decomposition rate of manure. Zameck (1966) reported that in a sandy loam soil the formation of NO_3-N was 13 per cent higher in the year of manuring than in plots which received mineral fertilizers,with average increases of 32 and 14 per cent after one and two years, respectively, after the last application of dung. Zameck (1967) found that application of 40 t/ha manure every two years along with basal N, P and K increased the NO_3-N in comparison with plots receiving N, P and K only. Lapnev (1967) observed that NO_3-N accumulation in soil in spring was the greatest when dung along with N,P and K was applied. From the incubation study Power (1968) reported that all mineral nitrogen was changed to nitrate form after 10 weeks of incubation at 30°C. Olsen *et al.* (1970) observed that production of NO_3-N was directly related to the rate of manuring, period of incubation, soil pH and presence of anaerobic conditions. It has been reported that addition of cow-dung, molasses or water hyacinth compost to two soils from delta flood plains of the Brahmaputra and Gangetic alluvial plains applied together with urea increased ammonification and tended to decrease nitrate accumulation (Khan and Rashid,1971). Sonoilenko (1973) found that N application increased NO_3-N content by 30-50 per cent but had less effect on NH_4-N. The NO_3-N of a clay loam soil, having received cattle manure over 3 successive years at the rate upto 224 t/ha, increased with increasing levels of manure and in the top of soil it was maintained at about 100 kg/ha by annual application of 224 t/ha manure. Giddens and Rao (1975) indicated that incorporation of manure into the soil greatly increased the amount of nitrogen oxidized to nitrate form. Sattar (1975) reported that the NO_3-N content of the soil increased gradually with incubation time and also with the increasing rates of Urea-N application. Similar results were obtained by Broadbent *et al.*(1958) and Acevedo and Pereira (1964). Hahne *et al.*(1977) noted an appreciable accumulation of NO_3-N in the soils under continuous cropping when the optimum rate of 140 kg N/ha was exceeded to 168 kg N/ha. Westerman and Tucker (1978) claimed that immobilization of

15 NO_3-N in soils with organic carbon amendments was increased markedly with increased temperature and time, but initial moisture content had little effect. It was observed by Shankhyan and Shukla (1978) that NO_3-N concentrations were generally higher in urea treated than in non-treated soil, higher in light textured than in heavy textured soils, and higher in non-saline than in saline soils. They further observed that the change in NO_3-N concentration with increasing incubation period was less in non-treated than in treated soil, and less in heavy textured than in light textured soils.

Vandani _et al._ (1979) noted an increased NO_3-N accumulation particularly in the deeper soil layers when repeated applications of liquid cattle manure were applied at rates varying between 75 and 300 m^3/ha. Gaur and Mukherjee (1979) observed that ammonical and NO_3-N contents which were 8.3 and 5.8 ppm, respectively, in the control, decreased to 1.6 and 0.83 ppm and 5.9 and 0.84 ppm in the treatment receiving 10 and 5 t/ha straw, respectively, after seven days. In the incubation studies More and Varade (1982) noticed that there was a rise in NO_3-N concentration with incubation time. A rapid increase in NO_3-N formation took place with increasing moisture from -25 to -33 bars water potential. The lowest NO_3-N content was found at -25 bars potential. Similar werethe results reported by Justice and Smith (1962).

Singh and Grewal (1983) reported that NO_3-N content of the soil increased significantly with the increasing levels of nitrogen. The distribution of NO_3-N in soils also varied with nitrogen doses. In control and 60 kg N/ha plots, it was more in the surface layers while in 120 and 180 kg N/ha plots, it was more in the sub-soil. The total and NO_3-N status of the soil was found to be improved after three years treatments of FYM as studied by Sharma (1986). Joshi et al.(1986) reported that time taken for appearance of NO_3-N was 8.41 days for urea.

2.1.2 Effect of organic manure and nitrogen on NH_4-N

Mineralization of organic nitrogen from FYM is generally too slow to provide appreciable nitrogen for crops with a short growing season (Jensen,1952).Among different organic materials FYM was found to have a low rate of ammonification and nitrification whereas groundnut cake had the highest rate (Sinha and Sharma, 1961).

Laidler and Hoare (1955) found that the ammonification rate of urea increased linearly with concentration. The ammonification rate of applied urea-N was found to be rapid in neutral soil (Temple, 1914) and lower in acid soil (Ostromecka, 1963). Jaiyebo and Bouldin (1967) reported that non-exchangeable NH_4-N showed an indefinite inverse relationship with the amount of added nitrogen fertilizer in plots receiving differential management for atleast 10 years. Power (1968) from the incubation studies indicated that NH_4-N decreased with incubation time. Sowden (1968) observed that percentages of total N represented by acid soluble N, amino acid-N, NH_4-N and amino sugar-N were similar in both clay and sandy soils, and were only slightly affected by additions of organic materials. Khan and Rashid(1971) observed in laboratory experiments that loss of gascious nitrogen from urea added to two soils from flood plains was markedly increased by addition of cow dung, molasses or hyacinth compost. They further observed that these organic materials were responsible for increased ammonification. That the nitrogen fertilizers tended to increase ammonia volatilization has been reported by Chai et al.(1974).

Pang et al.(1975) noticed that with the application of 100 kg N/ha, little or no oxidation of NH_4-N took place during the 1st week of incubation. They found after 2 weeks of incubation that nitrate present amounted to 36, 27 and 24 per cent of the banded urea, NH_4-OH and $(NH_4)_2$ SO_4, respectively, and the remainder was found as NH_4-N. Sattar (1975) observed an appreciable increase of NH_4-N upto 2 weeks after the application of urea-N and thereafter it decreased gradually with time. It was further noticed that increased rate of Urea-N resulted in increased concentration of NH_4-N.

Townsend (1977) reported that application of NH_4 NO_3 to a light sandy loam and a heavy silty clay loam soil revealed that, irrespective of whether soil was limed or unlimed, NH_4-N was neither nitrified nor lost during winter, but in summer much of the NH_4-N was nitrified when either the sandy loam or silty clay loam soil was limed. The production of NH_4-N was increased with the increasing levels of urea-N but the process of nitrification was depressed when urea-N was increased from 118 to 236 ug/g soil, as observed by Sarigumba et al.(1978). Kowalenko (1978) observed that nitrification of fertilizer nitrogen was very rapid with extractable NH_4-N approximating background level within the first 43 days of 15 N-labelled ammonium sulphate application to clay loam soil.

According to Puranik et al. (1978) NH_4-N was the highest in green manuring + FYM treatment followed by N, P and K and FYM treatments. Contrary to the above observations, Sharma (1979) reported that fertilizer treatments did not show any significant effect on NH_4-N and NO_3-N forms of nitrogen in an acid soil after three years of cropping. He further observed that lime application increased NH_4-N by about 30 per cent.

Sommers et al. (1979) reported that an insignificant amount i.e. 1 % of NH_4-N applied was lost through NH_3 volatilization from soils treated with sewage, sludges and antibiotic processing wastes. In a field study utilizing ^{15}N on Manotic sand, Kowalenko (1980) observed that leaching, denitrification, clay fixation of NH_4-N, mineralization and immobilization all played a significant role in the transport and transformation of fertilizer NH_4-N.

It was observed by More and Varade (1982) that there was little effect of moisture regime on the formation of NH_4-N in soil. In general, there was an initial increase in NH_4-N concentration attaining a peak and subsequently, it decreased gradually with time.

2.2 Effect of organic manure and nitrogen on organic carbon.

Considerable increase in the content of organic carbon was noted by Brage et al. (1952) in soils applied with 20 t/ha of manure over 30 years but 10 and 5 tons applications were found less effective in achieving the corresponding increases. Acharya and Rajgopalan (1956) observed 20 to 40 per cent increase over the unmanured check plot in the carbon content of the soil applied continuously with FYM at varying doses over a period of 25-45 years.

Prat et al. (1957) reported that application of ammonium sulphate and calcium nitrate for 28 years increased the carbon content of the soil. Similar results were obtained by Sundra Rao and Krishna (1963) and Sahu and Nayak (1971). Kanwar and Prihar (1962) reported that the application of organic manure and inorganic fertilizers maintained the organic carbon in a surface soil under wheat-fallow-wheat rotation. Chaudhry and Vachhani (1965) found no change in carbon content of soil even after continuous application of ammonium sulphate for 10 years. Similar were the results reported by Bandyopadhya et al. (1969).

Singh and Roysharma (1968) indicated that the organic carbon content did not increase considerably in a long term experiment by the application of FYM, whereas increased carbon content in the soil applied with FYM was observed by Singh and Mahant (1968) in an acid red clay loam soil. Chater and Gasser (1970) found that in a long term experiment the loss of organic carbon after cropping without organic manure can be recovered to the original percentage by the application of FYM.

Vig and Bhumbla (1970) noted significant increase in organic carbon content due to application of FYM. Increased level of organic carbon content in soils due to application of FYM alone or in combination with P and K was observed by Prasad et al. (1971). Sandhu and Meelu (1974) reported the continuous application of FYM to increase the organic carbon content in soil. Similar results were also observed by Mishra et al.(1974). Naphade and Bhoyar (1975) found increased level of organic carbon in the soil incorporated with FYM whereas the fertilizers were found little effective.

Russel (1977) was of the view that using normal farm dressings of FYM might increase the soil organic carbon content by just over 0.1 per cent. On the other hand, no significant increase in organic carbon in plots, which received chemical fertilizers, was observed by Acharya and Rajgopalan (1956). Significant increase in the organic carbon content of the soil as compared to the control was recorded by Ruhal and Shukla (1979) with the increasing doses of FYM.

Grewal and Trehan (1979) while studying the effects of organic and inorganic sources on potato in acid brown hill soil of Shimla reported that organic carbon content of the soil increased only by the continuous application of FYM@ 30 t/ha. It was reported by Sharma et al.(1980) from the long term manurial experiment on potatoes on acid brown hill soils of Shimla that FYM increased organic carbon and nitrogen contents of the soil substantially. Significant increase in pH and organic carbon due to continuous application of FYM was also observed by Grewal et al.(1981) while conducting a pot experiment.

Minhas and Bora (1982) observed highly significant positive correlations between the various forms of soil nitrogen including available nitrogen and the organic carbon content and so among the forms of nitrogen themselves.

In a long term rotational-cum-manurial field experiment in an alkaline sandy loam soil (pH 7.92) of Jalandhar, Singh and

Sharma (1983) reported that green manure was less effective than FYM in raising organic carbon status of the soil. Sharma (1986) from 3 years field study reported that FYM @ 30 t/ha improved organic carbon status of the soil.

2.3 Effect of nitrogen and organic matter on vegetative growth of potato.

It is generally assumed that vigour in haulm reflects the tuber yield but excessive vegetation is often at the expense of the storage reserves in the tubers(Pushkarnath,1967). A good vegetative growth is necessary for obtaining maximum yield (Bradley and Pratt, 1955) and there are reports by Sommerfeldt and Knutson (1968a) from their green house experiment that the top weight increased with nitrogen and the number of tubers per plant and their weight tended to decrease, especially at the higher rates. It was also observed that the root weight increased at the intermediate rates, that is, 60 to 120 lb N /acre . The same workers in the same year have also reported from the field study that major activity in tuber set and growth occurs in the later stages of plant development.

Singh (1975) reported that plant height did not differ significantly due to 250, 500 and 1000 q/ha FYM levels, but these had significant effect in increasing the plant height over control. The shoot height also increased as the rate of nitrogen increased at all stages of plant growth.It was further reported that the dry matter increased with various rates of FYM and nitrogen upto 45 days of planting. The highest level of FYM caused greatest dry matter production.In the same type of study Khurana *et al*. (1977) observed maximum height of potato in the treatment receiving 120 kg N/ha in combination with 100 kg each of P_2O_5 and K_2O/ha followed by 180 kg N in combination with the same levels of P_2O_5 and K_2O. The shortest plants were noted in plots receiving no fertilizers. The results were similar to the findings of Gupta (1969). Abdel-Maksoud et al. (1978) observed that application of nitrogen increased the number of stems, stolons and tubers per plant.It was further noticed that the tuber forming efficiency was greatest with low nitrogen levels in young plants but it was increased with nitrogen levels in older plants. A significant increase in number of stems per hill and increase in the height of main shoot with the increasing levels of nitrogen has also been reported by Hooda and Pandita (1980).

Sharma et al.(1980) reported that the yield of tops (pooled over all the three crops) showed a positive response of nitrogen upto 200 mg/kg soil when CAN was applied either alone or in combination with FYM. In the field study at Ludhiana,Sahota (1983) observed a progressive increase in the vegetative growth with the increasing levels of N (0 to 120 kg N/ha) at all dates of observations.

Govindakrishnan and Sahota (1984) found that application of nitrogen significantly increased the plant height or shoot number per plant over no nitrogen treatment.They also noticed that the haulm yield increased with the increase in nitrogen levels and delay in tuber initiation occured especially when applied at the time of planting.

Sahota and Sharma (1985) reported that higher levels of nitrogen (80 and 120 kg N/ha) delayed the emergence and developm of underground parts, including tubers, but accelerated the tuber formation later. Sharma (1986) from the experiment conducted in an acid sandy loam hill soil observed that there was highly significant response of haulm yield to nitrogen. The response, however, varied with the type of manuring. The effect of increasing rates of N on haulm yield was in line with its effect on tuber yield.

Widjajanto and Widodo (1986) reported that increasing rates of nitrogen fertilizer in combination with increasing rates of FYM increased plant height but had inconsistent effect on number of main stems per hill. They also reported that increasing rates of FYM increased the number of branches per hill.

2.4 Effect of different treatments on tuber yield and tuber size of potato.

2.4.1 Effect of nitrogen and organic matter on tuber yield and tuber size of potato.

2.4.1.1 Effect of nitrogen.

Judicious application of essential nutrients is a sure means of augmenting the yield of potato (Reddy and Rao, 1968). Nitrogen is the most important single nutrient for determining the yield of potato (Sharma, 1986) and the effect of nitrogen and organic matter plays an important role on the tuber yield and tuber size. Chucka et al. (1943) while studying the effect of rate of fertilizers on the yield and chemical composition of tubers in potato crop observed an appreciable increase in yield and change in composition of tubers. Russel and Garner (1941) on a similar study observed an increase in yield of potato by application of N,P and K fertilizers. It has, generally, been reported that nitrogen application gives higher response in comparison to phosphate and potash (Ramanujam and Singh,1956; Hawkins *et al.*, 1948). Singh and Singh (1953) obtained optimum yield of potato by application of nitrogen @ 90 kg/ha in study conducted on sandy soils. Studies conducted at Cornell Universit New York have shown that nitrogen application even upto 157 kg/ha increased potato yields (Sawyer and Dallyn, 1958). Anonymous (1962) observed N response even upto 252.3 kg N/ha. Black and Cairns (1958) conducted long term fertilizer studies for eight years in acid soils (pH 5.4 to 6.7) at New London Illustration Station in Prince Edward Island to study the effect of different levels of nitrogen (45, 90 and 135 lbs/acre) on the yield of potato. The analysis of the linear and quadratic effects of nitrogen revealed that the trend of N element in terms of increased yield was linear with no evidence of quadratic effect. The combined application of 112.1 kg N, 112.1 kg P_2O_5 and 224.2 kg K_2O/ha resulted in a significant yield increase of potato on the experiments conducted on the cultivators' field in Punjab (Kanwar, 1962). Reddy and Rao (1968) conducted farm experiment on sandy loam soil (pH 7.6) during November-March,1962 and 1963 and reported that with the increase in levels of nitrogen the yield incrsased significantly.Application of 56 kg and 112 kg N/ha gave an increase of 59.5 and 94.9 per cent, respectively, over no nitrogen treatment. The crop response per kg N at 56 kg N was significant for linear effect but the quadratic response was not found to be significant. The results thus indicated that the level for obtaining maximum yield was more than 112 kg N/ha. Hukkeri (1968) while conducting a field experiment in lateritic Hijli sandy clay loam soil (pH 5.4) at Kharagpur (West Bengal) in winter under irrigated conditions reported that 90 and 135 kg N/ha significantly increased the yield of potatoes over 45 kg N/ha. In the farm experiment conducted at the Indian Agricultural Research Institute in alluvial sandy loam soil of medium fertility, Singh et al.(1968) reported that the increase in the level of nitrogen application from 56 kg N/ha to 112 kg N/ha tended to increase the yield significantly in two of the three years of study. Application of the highest dressing of 168 kg N/ha which did not improve upon the response to 112 kg N/ha, proved a luxury dose. Sahu (1973) reported from his experiment conducted on alluvial and sandy loam soils of Orissa that the yield of potato was the highest with 80 kg N/ha and decreased linearly due to application of higher doses. Singh (1975) and Henninger et al.(1977) observed an increase in mean tuber yield of potato by application of different levels of nitrogen over zero levels. Khurana et al. (1977) reported that nitrogen gave linear response upto 180 kg/ha. The highest average yield of 369.5 q/ha was obtained under the combined treatment of 180 kg N, 50 kg P_2O_5 and 50 kg K_2O/ha. Sadaria (1978) in a study on the effect of nitrogen on potato crop conducted at Palampur under mid hill conditions obtained highest yield of application of 120 kg N/ha applied in 2-3 splits. Sharma et al.(1978) found that the tubers continued to accumulate the nutrients till maturity, and the accumulation was rapid during 65-85 days which corresponded to tuber initiation and early bulking stage of the crop and can be regarded as the critical stage for absorption of primary and secondary nutrient The findings hold good for Kufri Jyoti which is the main variety of the hills. Grewal et al.(1979) while working in field experiments conducted in acidic brown hill soils of Shimla found that the tuber yield increased with an increase in the level of nitrogen upto highest level, but the differences between 80 and 120 kg N/ha were not significant. De and Singh (1959) also observed significant increase in potato tubers by application of nitrogen upto 75 kg/ha. Sikka and Singh (1969) and Grewal et al.(1976) observed that the split application of N was better than full application in furrows in alluvial soils of Jallandhar. Giroux (1982) obtained higher yield of potato with increasing levels of N (130-210 kg N/ha). However, Santeliz and Ewing (1981) obtained a reduction in tuber yield and delayed maturity by the application of increasing rates of N (0-268 kg N/ha). Koening et al.(1981) grew potatoes on an irrigated loamy sand to compare different nitrogenous fertilizers and found that NH_4-N source tended to produce higher yield than NO_3-N source but urea and ammonium sulphate showed considerable differences. Clutterbuck and Simpson(1978) reported a significant response of tuber yield to nitrogen even upto the highest rate tested (300 kg N/ha). Verma and Grewal (1983) reported that nitrogen response by potato showed increasing trend upto the highest level of 120 kg/ha. The pooled data of 4 years showing significant responses upto 180 kg N/ha has been reported by Singh and Sharma (1983) on alluvial sandy loam (pH 7.92) soil of Jallandhar. Singh and Grewal

(1983) reported that the tuber yield increased linearly with the increase in nitrogen levels upto 180 kg N/ha but the response per kg nitrogen decreased with increased nitrogen doses. The earlier studies by Pushkarnath and Sardana (1964), Pushkarnath *et al.*(1971), Grewal and Sharma (1978), Ram *et al.* (1979) also showed that per unit N response decreased with increasing nitrogen levels. Singh and Sharma (1983) in a similar type of study conducted on alluvial soils of Jallandhar (pH 7.9) obtained increased yield of potato tubers and N concentration of tubers with the increasing levels of N.Jagirdar *et al.*(1984) found significant effect on yield of potato with increasing levels of nitrogen upto 187 kg N/ha over 132 and 110 kg N/ha, respectively. Grewal *et al.* (1984) on the basis of field experiments conducted at four locations of Central Potato Research Institute, reported that at Jallandhar and Patna,potato responded significantly to nitrogen application upto 180 kg N/ha and at Babugarh upto 120 kg N/ha. Dixit and Sharma (1985) observed highest tuber yields with 120 kg N/ha applied to the soil in two split dressings at planting and earthing up followed by 120 kg N applied at planting. Similar results were observed by Grewal and Sharma (1980) and Sahota *et al.*(1984). Satyanarayan and Arora (1984) reported that tuber yields of potato increased by increasing the N rates upto 150 kg/ha. Govindakrishnan and Sahota (1984) conducted an experiment at Shillong and Shimla and reported that application of nitrogen significantly increased the yield of tubers upto 100 kg N/ha, and the difference between 100 and 150 kg N/ha was non-significant at both the places.

Trehan and Grewal (1984) while working in acidic brown hill soils of Fagu(Shimla) reported that application of 100 kg N + 20 kg P_2O_5 + 40 kg K_2O/ha (5:1:2) significantly increased the tuber yield from 126.6 to 291.1 q/ha.

The increasing doses of nitrogen have been reported to increase the size of potato (Mass, 1963; Hanlay et al.,1965). The observations of Sommerfeldt and Knutson (1968,b) revealed that the increase in the size of different grades of potato was possible only under field conditions and not under pot culture. Nitrogen levels at 56 and 112 kg N/ha gave an increase of 61.8 and 120.4 per cent of big sized tubers and 19.00 and 41.9 per cent of medium sized tubers, respectively, as reported by Reddy and Rao (1968). This is in accordance with the findings of Russel and Garner (1941), Singh (1952) and Anonymous(1960). An increase in the yield of ware sized tubers by the applicatio of different doses of nitrogen has been reported by Hukkeri (1968). Herlihy and Carroll (1969) reported that size distribution of tubers was influenced by nitrogen which increased the proportion of large tubers and decreased that of other grades.

The experimental results of two years field study made by Sahota and Govindakrishnan (1984) also confirmed that the application of nitrogen in combination with phosphorus and potash results in the increase in the yield of tubers of different grades. Similarly, Sharma (1986) concluded from his study at Shimla that the increasing rate of nitrogen is responsible for the increase in the yield of large grade tubers (100 gm) and that this effect is more conspicuous when nitrogen is applied along with P and K. Increase in the yield of medium grade potato (50-100 gm) due to N application also took place but the magnitude of increase was less than the large grade tubers. The increase in the yield of large sized tubers due to the application of different nitrogen levels has also been reported by Singh and Grewal (1983), Sikka and Singh (1969) and Singh and Paliwal (1978). Contrary to the above observations, White and Sanderson (1983) did not observe any effect of increase in nitrogen application on per cent grade size distribution of potato tubers.

2.4.1.2 Effect of organic manure:

The effect of organic manures in conjunction with inorganic sources of nutrients could lead to the increased efficiency of the latter and fairly a good amount of it could be substituted by the former (Russel and Garner, 1941). Singh (1975) reported that increase in mean yield of potato was due to various levels of FYM over zero levels. The soil organic matter affected the tuber production mostly through its influence on N, P and K availability and the relationship (linear and quadratic) of organic matter with the yield was found to explain 36 per cent variation due to quadratic model and 32 per cent variation in yield due to linear model (Sharma et al., 1981).

In a two years field study conducted by Grewal and Trehan (1984) on the efficiency of FYM on potato in an acid soil of Shimla, it was observed that significant increase in the production of large tubers ($>$ 75 g) was obtained with 30 t FYM/ha.

2.4.1.3 Combined effect of nitrogen and organic manure.

Being a tuber crop, potato requires comparatively organic matter rich soils with high contents of nitrogen, phosphorus and potassium (Singh, 1975) and for better tuberization and high yields addition of FYM in combination with nitrogen has been reported by different workers(Dimitrov, 1964; Below, 1968; Shloma, 1968 and Singh and Singh,1971). Singh et al.(1968) who conducted two years field experiment at Patna to study the influence of manurial factors on the yield of potato observed that organic manure increased the yield, but it did not interact with other factors except nitrogen and variety. The response of farm yard manure decreased as the level of nitrogen increased. Singh (1975) reported that the best combination of FYM and N for obtaining maximum yield of potato tubers was that of 100 kg nitrogen and 1000 quintals FYM. The increase in yield by this treatment over control was more than the total increase by 100 kg nitrogen or 1000 quint. FYM alone. Similar type of results were also observed by Wickens (1963), Dimitrov (1964), Below (1968), Shloma (1968) and Singh and Singh (1971). Grewal and Sharma (1978) observed to increase the response of potato to nitrogen application in the presence of FYM in soils having low organic carbon content. Sharma et al.(1978) reported that FYM improved the N responses in acid hill soils of Shimla and there was positive interaction between FYM and nitrogen. The responses were significantly marked upto 80 kg N/ha in the absence of FYM and upto 120 kg N/ha in the presence of 20 and 40 t FYM/ha. The yield potential was higher in the presence of 40 t FYM/ha than 20 t FYM/ha. Vanha

(1978), however, obtained highest tuber yield of 350 q/ha by the application of 25 t FYM + 120 kg N/ha with adequate phosphate and potassium. Sharma et al. (1980) reported from pot culture studies that CAN + FYM gave 2.67 times higher tuber yield than CAN alone. The increased efficiency of N by 20-25 % and increased responses of potato to N with the application of FYM has been reported by Ionas (1980). Similar results have also been reported by Timm et al. (1963); Sharma and Rao (1972); Rykbost and Catas (1977); Ram et al. (1979); Grewal and Sharma (1981); and many other workers. The combined application of FYM and nitrogenous fertilizer to seed crop of potato leads to the production of higher tuber yielding potential than the combined application of N, P and K (Sharma and Sharma, 1981) and besides the length of crop duration, organic manures affected the response to nitrogen and the treatment that received FYM remained superior even at high rates of nitrogen (Singh and Sharma, 1983). The increased efficiency of nitrogen and increase in yield of potato by the application of FYM in combination with N fertilizers has also been reported by Sahota and Grewal (1984) in acid soils (pH 4.7 - 5.4) of Meghalaya. They further observed that FYM application at the rate of 20 t/ha reduced P needs of crop from 37 to 28 kg P_2O_5/ha. In a three years field study on an acid soil of Shillong, Sahota et al. (1984) reported that there was highly significant response of potato to 40 t/ha FYM + 120 kg N/ha + 25 kg P/ha.

In a study conducted by Mondal et al. (1985) on sandy loam soil of West Bengal, it was observed that organic sources of nitrogen were found to be as effective as inorganic sources and among organic sources oil cake was found to be more effective than FYM. Highest yields were recorded by supplying one fourth N through oil cakes and three fourth nitrogen through urea in both years. Widjajanto and Widodo (1986) reported that maximum marketable tuber yield was achieved with the application of 20 t FYM in combination with 180 kg N/ha.

Application of 120 and 80 kg N/ha along with 30 t FYM/ha improved the yield of large grade tubers (Sharma, 1986).

2.4.2 Effect of nitrogen and irrigation on tuber yield and tuber size of potato.

Among the factors influencing potato production, water and nitrogen supply have an important place (Singh and Grewal, 1983). Singh and Swaminathan (1957) reported that there was a strong positive interaction between irrigation and nitrogen. Nitrogen efficiency increased with the improvement in the moisture status of the soil. Frequent irrigations also enhance the response to nitrogen. Similar results have also been reported by Chakravarti (1958). In a similar type of study significant interaction between irrigation and nitrogen was found by Singh and Grewal (1983). It has been reported by Sood and Sharma (1985) that the crop invariably under moisture stress from germination to stolonization adversely affected the tuber yield. Contrary to the above statement, Gates(1955) reported that delay in irrigation at early vegetative stage (Stolon formation) did not affect the yield adversely. Singh et al. (1968) reported from an experiment conducted in loamy soil of low fertility at I.A.R.I. that even though there was considerable variations in the yield levels of potato from year to year, but there was response to irrigation in all the years. The top 30 cm soil layer contributed 67-73 per cent of the total water use by the potato. Moisture depletion decreased with soil depth. The peak rates coincided with the tuberization phase and were 4.7, 3.5 and 2.9 mm per day in wet, moist and dry regimes, respectively. It was observed that frequent irrigations at low soil moisture tension (0.20-0.30 atmosphere) increased the tuber yield in all the years. It was also reported from the pooled analysis that wet regime raised the yield by 43 q/ha as compared to dry regime. It was further noted that delayed irrigations reduced the yields, even though the moisture percentage before tuber initiation was well above the wilting point. Similar findings have also been reported by other workers (Taylor, 1952; Jones and Johnson, 1958; Myhre, 1958; Bhattacharjee, 1960) who studied the response of potatoes to irrigation at varying soil moisture regimes. Hukkeri et al. (1970) observed that in Kufri Sindhuri the moisture stress (0.5 atm.) did not reduce the yield significantly during first 20 days after planting but there was significant reduction in yield when the moisture stress was given during 20 to 40 days after planting. It was also noted that mild as well as severe moisture stress in the third stage of crop development (slow bulking to maturity) did not affect the yield at all.

Yadav and Tripathi (1972) reported that soil moisture regimes had a well marked effect on the yield of potato tubers. An average yield of 263.7 q/ha was recorded under treatment of available moisture, which was increased by 13.8 and 33.8 per cent under soil moisture regimes of 50 and 75 per cent available moisture, respectively. The effect of different irrigation frequencies at different growth stages was studied by Jorgensen (1979) in potato and the highest tuber yields were obtained with short or normal irrigation intervals during tuber formation and tuber growth stage. In the same type of experiment, Imam et al.(1975) studied the effect of irrigation and organic manuring on tuber yield and they observed that the tuber yields were significantly increased at higher moisture levels and the application of two rates of FYM did not significantly increase tuber yield but the highest yield was obtained with the highest rate of both water and manure. Henninger et al.(1977) observed that irrigation increased the tuber yield on both mulched and unmulched plots. While studying the soil moisture stress at different crop stages on tuber yield, Singh and Grewal (1979) from their two years field study on alluvial sandy loam soils of Babugarh and Modipuram (U.P.) reported that mild moisture stress (0.5 atm.) during first stage of crop growth i.e. before tuber initiation did not cause any reduction in yield but imposition of severe moisture stress (0.7 atm.) at this stage had adverse effect on yield. The moisture stress during second stage of crop growth i.e. tuber setting and enlargement had harmful effect on tuber yield. The soil moisture stress during third stage of crop i.e. slow bulking to maturity did not affect the tuber yield.

In a study to see the relation of water supply and yield of potatoes in relation to fertilizers and irrigation, potatoes were grown with or without irrigation and it was observed by Alekseeva (1979) that the tuber yields were the highest with deep ploughing, fertilizers and irrigation.It was also noticed that the water consumption per unit yield was reduced 2-fold with FYM and NPK. Singh and Grewal (1983) observed in the field experiments on sandy loam alluvial soil (pH 7.3) of Patna that the highest potato responses to 60, 120 and 180 kg N/ha were recorded at 15 mm CPE. The nitrogen responses decreased when irrigation was delayed to 20,25 and 30 mm CPE. It was further noted that at 60 kg N, irrigation may be delayed upto 25 mm CPE without significant decrease in tuber yield. The optimum nitrogen dose varied with the water supply.It increased with the increase in irrigation level. The response to optimum nitrogen doses also decreased with the decrease in irrigation frequency. Singh et al. (1968), Bhan and Shankar (1975) and Singh and Paliwal (1978) also reported similar results.

As in case of nitrogen, various workers have reported significant effect of irrigation on the size of potato tubers. Higher yields of medium sized tubers were obtained by Singh and Grewal (1983) with irrigation at 15 or 20 mm CPE. The studies on the interaction effect of irrigation and fertilizers made by Blanko (1982) revealed that with the increase in the soil moisture content there was increase in the number of large tubers but decrease in their specific gravity.Singh et al.(1968) and Singh and Paliwal (1978) also reported similar results.

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2.5 Effect of nitrogen and irrigation on quality of tubers.

The chemical composition of tubers is affected by factors like rate of fertilizer application, the proportion of N, P and K in the fertilizers, manures, seasonal conditions and type of rotation etc. (Chucka et al., 1943) and the quality of tubers is also affected by amount of water available to the crop during its active growth phase (Struchtemeyer, 1961). That the amount and kind of fertilizer applied to potato can also have a significant effect on quality of potato has been reported by Prince et al. (1940), Smith (1940) and Terman (1950). They have further reported that liberal use of complete fertilizer may increase yield, but at the same time reduce starch content.

Black and Cairns (1958) reported that there was a highly significant reduction of starch content of potato due to increase in the levels of nitrogen and K while no significant effect of P application was recorded. The reduction was in the order of 0.64 per cent for low versus high level of nitrogen. An average reduction in starch of only 0.03 per cent followed the application of manure. Similar results were also reported by Anonymous (1960) and Sinha et al. (1967).

Reddy and Rao (1968) observed that the starch percentage recorded at 0, 56 and 112 kg N/ha levels was 46.8, 44.7 and 44.1, respectively. They observed that application of N decreased starch content whereas P and K application increased it. Similar results were obtained by Hukkeri (1968). Yadav and Tripathi (1972) also reported that higher levels of nitrogen reduced the starch content but increased the protein content significantly at each level of nitrogen. However, Kamal et al. (1974) observed an increase in starch content of potatoes due to increase in the levels of nitrogen, P and K.

Majur and Gawlick (1977) also observed that increase in nitrogen application resulted in decrease in starch content of potato tubers and reduction in the content of reducing sugars from 1.40 per cent at 120 kg N/ha to 1.22 per cent at 240 kg N/ha application. Other workers like Barsukov (1982) also found a decrease in starch content of potato tubers due to application of N and FYM. No significant effect of nitrogen application on starch content of tubers was, however, found by Vender and Cremaschi (1980).

Prince and Blood (1962) reported that irrigation tended to lower specific gravity either directly by increasing yield or indirectly by lowering starch formation or by increasing moisture content of the tubers or both. Supersperg(1967) also reported reduction in the starch content of potato tubers with more frequent irrigations. Yadav and Tripathi (1972) reported that higher levels of soil moisture reduced starch content and showed slight increases in the protein content of tubers.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

In order to achieve the objective of the title, "Response of potato to nitrogen as influenced by irrigation and organic matter", a field experiment was conducted at the research farm of the Department of Soil Sciences and Water Management, Himachal Pradesh Krishi Vishva Vidyalaya, Palampur during Spring 1984 and 1985.

The research farm is situated at 32.6^{o}N latitude and 76.3^{o}E longitude at an altitude of 1290 meters above mean sea level. The soil of the experimental field falls in the order 'Alfisol' and has been classified as "Typic Hapludalf" at the sub-group level (Verma, 1979). The soil owes its origin from parent materials like slates, phyllites, quartzites, schists and gneisses.

3.1 Climate of the experimental area

The experimental area falls under the wet temperate zone in the outer Himalayas. The mean annual rainfall recorded at the Meteorological Observatory, Palampur shows a range between 2500-3000 mm out of which a major portion (more than 75%) is received during the monsoon season i.e. from June to September. From the crop sowing to harvest 211.9 mm and 212.2 mm rainfall was received during 1984 and 1985, respectively. The mean minimum temperature during 1984 ranged from 4.2^{o}C in February to 20.2^{o}C in June and maximum temperature from 15.4^{o}C in February to 33.10^{o}C in May, whereas, during 1985 mean minimum temperature ranged from 4.4^{o}C in January to 18.8^{o}C in May and maximum temperature ranged from 14.2^{o}C in January to

31.0°C in May. The average of minimum and maximum temperatures varied from 9.8°C to 26.6°C in 1984 and 9.2°C to 24.9°C in 1985. The maximum and minimum relative humidity values during the two seasons varied from 29 per cent in May to 66 per cent in June during 1984 and from 46 per cent in May to 72 per cent in February during 1985.

The mean monthly meteorological data pertaining to the period of experimentation, as recorded at the Meteorological Observatory of the Himachal Pradesh Krishi Vishva Vidyalaya, Palampur are presented in Table 3.1.

Table 3.1 Meteorological data for crop seasons of 1984 and 1985 as recorded at the Meteorological Observatory, HPKVV, Palampur

Months	Mean monthly temperature (°C)				Relative Humidity (%)		Rainfall (mm)		Rainy days	
	Maximum		Minimum							
	1984	1985	1984	1985	1984	1985	1984	1985	1984	1985
January	-	14.2	-	4.4	-	66	-	26.6	-	3
February	15.4	17.8	4.2	6.4	53	72	114.6	27.4	4	2
March	25.0	23.7	11.9	11.9	45	69	35.9	26.4	3	3
April	26.0	25.9	14.6	14.7	39	56	27.0	80.2	7	8
May	33.1	31.0	20.1	18.8	29	46	34.4	51.6	4	4
June	29.1	-	20.2	-	66	60	-	-	-	-

During the crop season the total number of rainy days was 18 and 20 in the years 1984 and 1985, respectively. The total rainfall before germination but after planting of the crop was much higher in 1984 in comparison to 1985 and was 127.4 mm and 27 mm, respectively. Thus, the rainfall during crop period after germination was 84.5 mm and 185.0 mm during 1984 and 1985, respectively, although the total rainfall from the date of planting to harvest during both the years was almost the same i.e. 211.9 mm and 212.2 mm in 1984 and 1985, respectively.

The details of the materials used and experimental procedures adopted in the study are given below:

3.2 Experimental details:

The experiment was conducted in a Randomized Blocks Design with three replications.

3.2.1 Treatments

The performance of the following treatments was investigated during both the years of experimentation.

a) Irrigation levels: Two

(i) I_0 = Rainfed

(ii) I_1 = Irrigated ($\frac{I.W.}{C.P.E.} = 1$)

where, I. W = depth of irrigation water.

C.P.E. = Cumulative pan evaporation.

b) Organic matter levels: Three

(i) M_0 = No incorporation of organic matter.

(ii) M_1 = Incorporation of freshly chopped *Lantana camara* @ 10 t ha^{-1} on dry weight basis.

(iii) M_2 = Incorporation of FYM @ 10 t ha^{-1} on dry weight basis.

c) Nitrogen levels: Three

(i) N_1 = 40 kg N/ha

(ii) N_2 = 80 kg N/ha

(iii) N_3 = 120 kg N/ha

The total treatment combinations were eighteen.

3.2.2	Total number of plots	=	54
	Gross plot size	=	3 x 4 = 12 m^2
	Net plot size	=	2 x 3 = 6 m^2
	Spacing.		
	Inter row spacing	=	50 cm
	Intra row spacing	=	25 cm

Each plot contained six rows and 16 number of potato tubers were sown in each row. Thus a total number of 96 tubers was sown in each plot.

Variety: Kufri Jyoti

3.3 Preparation of the field

The experimental field was prepared with the help of tractor driven disc plough and harrow. The lay out of individual plots was carried out by manual labour. Since the experiment included irrigation treatments also, the bunds between the treatments were kept 60 cm wide.

The treatments were randomised using random numbers. The lay out of the experiment remained the same in both the years. To avoid residual effect, black gram was sown on 30th July, 1984 and harvested on 19th October, 1984 without application of fertilizers and manures. The lay out plan of the experiment is given in Fig. 3.1.

Irrigations of 6 cm depth were applied at 1.00 I.W./ C.P.W. ratio. Half of the nitrogen, 80 kg P_2O_5 and 60 kg K_2O per hectare were applied at the time of sowing and the remaining nitrogen was applied at the time of earthing up. The N, P and K were applied through urea, single superphosphate and muriate of potash, respectively. The fertilizers and organic manures were applied in 3-4" deep furrows and tubers were planted above

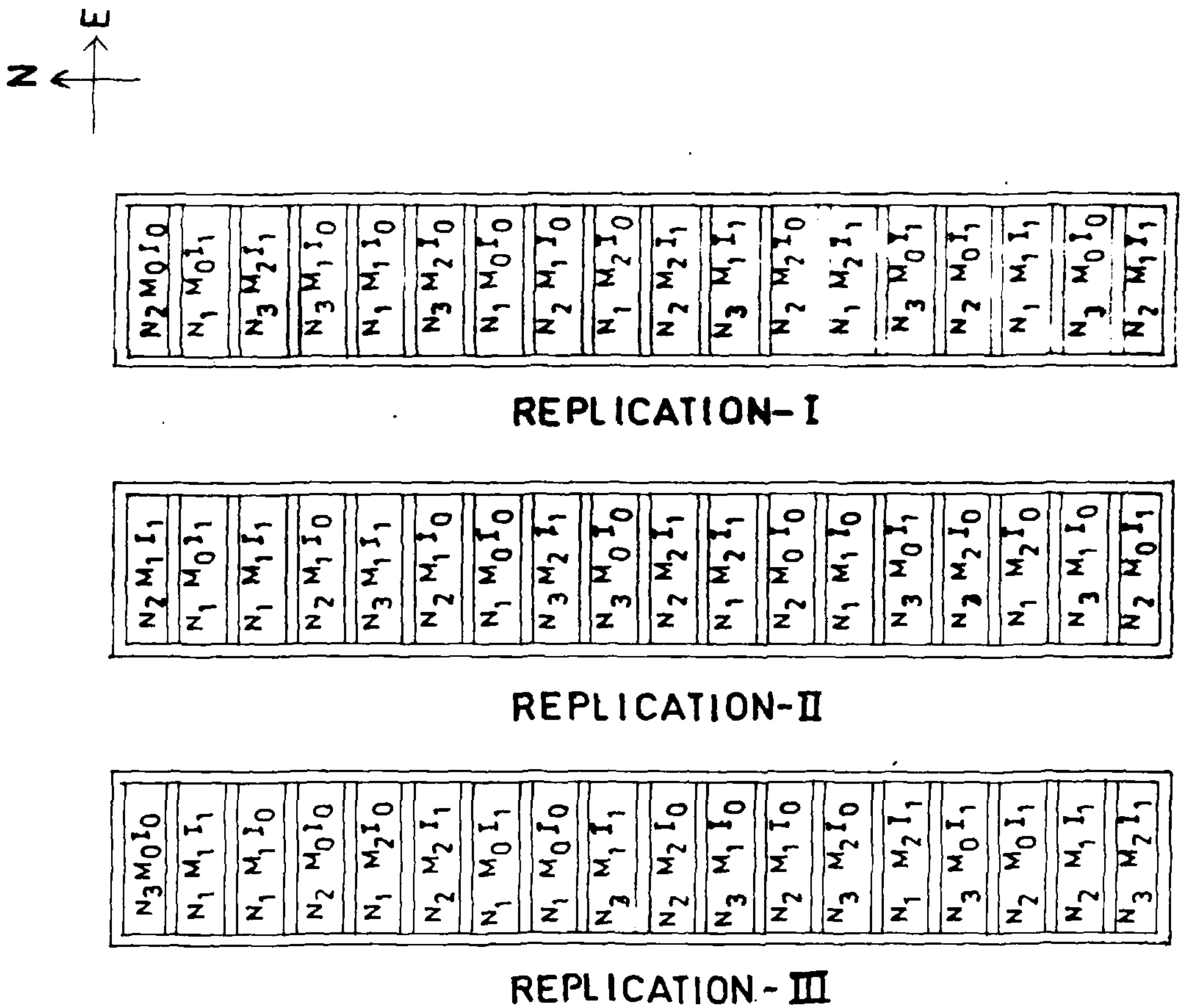

FIG-3.1-PLAN OF LAYOUT

the fertilizers, followed by covering up with earth taken from each side.

Cultural Practices followed:

The schedule of cultural operations followed during the period of experimentation is given in Table 3.2.

Table 3.2 Schedule of Cultural Operations

S. No.	Operations	1984	1985
1.	Date of sowing	10.2.84	17.1.85
2.	Weeding	15.4.84	17.3.85
3.	Top dressing of N	1.5.84	6.4.85
4.	Earthing up	1 and 2.5.84	18 and 19.4.85
5.	Irrigations	2,13 and 25.4.84	9 and 21.3.85
		3,10,19 and 25.4.84	4,17 and 25.5.85
6.	Plant protection measures against:		
	i) Cut worms	14.5.84 (5% aldrin dust)	20.4.85 (5% aldrin dust)
	ii) Late blight	25.4.84 (0.2% Fytalon)	
7.	Date of Harvesting	4.6.84	1.6.85

3.5 Observations recorded:

3.5.1 Growth studies:

a) Germination:

Number of plants germinated in each plot were counted from the start of the germination for almost a month at regular interval of four days.

b) Plant height:

Five plants were selected randomly from central rows of the plots and height of these plants was measured from ground level upto the tip of the plant and the average height of five plants was taken as the mean height.

c) Number of branches:

Number of branches from above ground level to the apex of the plant were counted from the five plants selected for plant height and the average of the five plants was calculated.

d) Number of leaflets:

The number of leaflets were counted from the same five plants and the averages were calculated.

3.6 Studies at harvest:

a) Dry weight of the shoot:

Fresh weight of shoots was recorded from each plot at the time of harvest and representative shoot samples were dried in the oven at 65°C till the weight became constant. From this the dry weight of shoots per plot was calculated and expressed in q/ha.

b) Tuber yield:

Tuber yield from each plot was recorded and expressed in q/ha.

c) Grading:

Potato tubers were categorised in three grades i.e. lar (more than 50 gm), medium (between 25 and 50 gm) and small (less than 25 gm). The graded potato tubers from each plot were weighed separately and the weight of each category expre q/ha which was ultimately expressed in percentage of the t

3.7 Soil studies:

3.7.1 Soil temperature:

Daily soil temperature was recorded with the help of ordinary thermometer from a depth of 6 cm at 6.30 A.M. and 2.30 P.M. from the date of sowing till the harvest of the crop.

3.7.2 Moisture study:

Soil samples after every seven days from the date of sowing till the harvest were collected with the help of tube augar from a depth of 0-20 cm from each plot and moisture content was determined by drying the samples in an electric oven at 105°C for 24 hours till it reached a constant weight.

3.7.3 Bulk density:

Bulk density at 0-15 cm soil depth was determined in the field before sowing of the 1984 and 1985 crops. This was done with a metallic core having 10.5 cm internal diameter and 14.2 cm height. The core had a sharp edge at one end to facilitate easy penetration into the soil, following hammering by a centre weight concentrated hammer. The fresh weight of soil was recorded and the moisture content in the soil was determined by gravimetric means.

3.7.4 Infiltration rate:

The infiltration rate of the soils of study area was determined after harvest of each crop using double ring infiltrometers. The infiltrometers were filled with water and intake was measured as a function of time until a steady state was reached (Haise *et al.*,1956).

3.8 Laboratory studies:

The soil samples collected from 0-20 cm depth were subjected to physical and chemical analysis in the laboratory for the determination of the following parameters(Table 3.3).

a) Particle size was determined by the International Pipette method (Piper, 1966) while the water holding capacity was determined by the Keen box method (Piper, 1966).

b) pH of the soil was determined in 1:2.5 soil: water suspension by using glass electrode pH meter (Jackson,1973).

c) Organic carbon was determined by the wet digestion metho (Walkley and Black,1934).

d) Cation exchangeable capacity was determined by extraction with neutral normal ammonium acetate (Chapman,1965).

e) Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956).

f) Available P_2O_5 was estimated by Olsen's method(Olsen *et al.*, 1954).

g) Available K_2O was determined by ammonium acetate,pH 7.0 method (Marwin and Peech, 1951).

h) Nitrate-N and Ammonium-N:

Nitrate-N and ammonium-N contents in the wet soil were determined at every 20 days interval from the date of sowing till the harvest by colorimetric method of Onkan and Sunderman(1977). Twenty gm fresh soil sample was used for the extraction of nitrate-N and ammonium-N by 1 N sodium sulphate solution. The values of nitrate-N and ammonium-N were expressed on oven dry weight basis of the soil.

Table 3.3 Physico-chemical properties of the surface soils of study area before conducting the experiments

Soil parameter	Content in soil 1984	1985	Method employed
A. Mechanical Composition			
Sand (%)	32.07	32.07	International Pipette method(Piper,1966).
Silt (%)	37.08	37.08	
Clay (%)	29.26	29.26	
Textural class	Clay loam		
B. Chemical Composition			
pH	5.70	5.76	In 1:2.5 soil water suspension with glass electrode pH meter (Jackson,1973)
Organic Carbon(%)	0.72	0.85	Walkley and Black(1934) wet digestion method.
Available nitrogen (kg/ha)	357.0	367.0	Alkaline permanganate method(Subbiah and Asija, 1956).
Available phosphorus(kg/ha)	21.0	22.0	Olsen's method(Olsen *et al.*,1954).
Available potash (kg/ha)	263.0	266.0	Flamephotometric method (Marwin and Peech,1951)
C.E.C.(m.e./100 gm)	11.48	11.48	(Chapman, 1965).
Water holding capacity (%)	36.62	37.20	(Piper,1966)

Nitrate-N:

Nitrate-N was determined quantitatively in 3 ml sodium sulphate extract by adding 7 ml chromotropic acid (0.01%). The colour intensity was measured spectrophotometrically at 430 nm using blue filter. Standard curve was prepared by developing colour as mentioned above from known concentrations of samples prepared from potassium nitrate. A blank test was also followed so as to adjust the readings.

Ammonium-N:

To an aliquot of sodium sulphate extract 1 ml sodium potassium tartrate was added and solution brought to a temperature of 25°C. The colour was developed by adding 2 ml Nessler's Reagent. The colour intensity was measured at 435 nm spectrophotometrically. Standard curve was prepared by developing colour as mentioned above from known concentrations of samples prepared from ammonium sulphate. A blank test was followed so as to adjust the readings.

h) Quality analysis of Tubers:

i) Starch content:

Starch content was determined by colorimetric method (Mc Cready et al.,1950). Starch was first made free from sugars by treating the samples with 80 per cent ethanol. It was then extracted with 52 per cent perchloric acid by constant stirring. The colour was developed in the extract by adding anthrone reagent and the intensity of the colour developed was measured spectrophotometrically at 625 nm using blank as standard. Standard curve was prepared by using glucose as standard. Starch content was calculated by multiplying the equivalent by 0.90.

ii) Estimation of reducing Sugars:

Reducing sugars in potato tubers were determined spectrophotometrically (Lindsay, 1973). One ml of water and 2 ml of dinitrosalicylic acid reagent were added to the sample and heated in boiling water bath for 10 minutes. A blank solutio without sample was also prepared in the similar manner. It was then cooled and the colour developed was read on spectrophotomet at 570 nm. Standard curve was prepared from glucose versus per cent transmittance at 570 nm.

iii) Estimation of non-reducing Sugars:

Total sugar content was first determined after acid hydrolysis (AOAC, 1955) as reducing sugars. The value for non-reducing sugars was obtained by multiplying the differences between total sugar and reducing sugars by 0.95 (Verma *et al.*, 1973).

3.9 Statistical analysis:

Observations recorded during the course of experiment were subjected to the statistical analysis as described by Cochran and Cox (1963). The level of significance was tested at 5 per cent.

EXPERIMENTAL RESULTS

4. EXPERIMENTAL RESULTS

To see the response of potato to nitrogen, irrigation and organic matter studies were conducted with regard to soil available N status during the crop growth, soil physical characteristics, growth and development of potato, tuber yield and different quality parameters. The findings are given in the following sections.

4.1 Soil characteristics as affected by different treatments

4.1.1 NO_3-N and NH_4-N in soil:

The NO_3-N and NH_4-N content in 0-20 cm depth determined at regular intervals of 20 days after planting is given in figs. 4.1 - 4.3. The treatment effects, main effects and analysis of variance are given in appendices I to XII and XXI to XXIV. In general, the content of NO_3-N in the year 1984 was higher during the period of 40-60 and 100 days after planting (Fig.1). The content of NH_4-N also, in general, during 1984 was higher during the period of 40-60 and 100 days after planting. The content of both NO_3-N and NH_4-N after 80 days of planting, when second dose of nitrogen was applied, increase rapidly upto 100 days after planting to maximum values and thereafter began to decrease.

In general, the availability of NO_3-N during 20 days after planting in the year 1984 was low, which strikingly rose up during the period of next 20 days. However, the same trend was not noticeable for NH_4-N during the same period.

During the subsequent year, i.e. 1985 the content of NO_3-N, in general, increased with time upto 60 days after the basal dressing. The trend later on upto the time of second dressing could not be known as the next sampling dose fell after the second nitrogen dressing. The content of NO_3-N declined with time after the second dressing made after 79 days of sowing. During the same year the content of NH_4-N was the highest after 20 days of first application at planting. The content then declined upto 40 days and again increased upto the date of second dressing i.e. 79 days after planting . However, after second dressing the content showed a decreasing trend.

4.1.1.1 Effect of nitrogen application on availability of NO_3-N and NH_4-N

It is evident from the data given in tables 4.1 and 4.2 that the increase in NO_3-N at different dates of sampling during both the years was significant with increasing levels of nitrogen except on 1-3-1984 with 80 kg nitrogen level over 40 kg/ha (Table 4.1). However, the increase in NH_4-N with increasing levels of N was not significant in some of the dates of sampling (Table 4.3 and 4.4). During both the years the content of both NO_3-N and NH_4-N increased with increasing rates of fertilizer nitrogen (Tables 4.1 - 4.4). During the year 1984, the increase in NO_3-N content due to nitrogen levels of 80 and 120 kg/ha was comparatively more compared to the dose of 40 kg N/ha, during 40-60 days and at 100 days of crop growth(Fig.4.1). However, there was relatively greater increase in the NO_3-N content during 1985 with 120 kg N/ha application both after first and second dressing over the lower two doses (Fig.4.1).

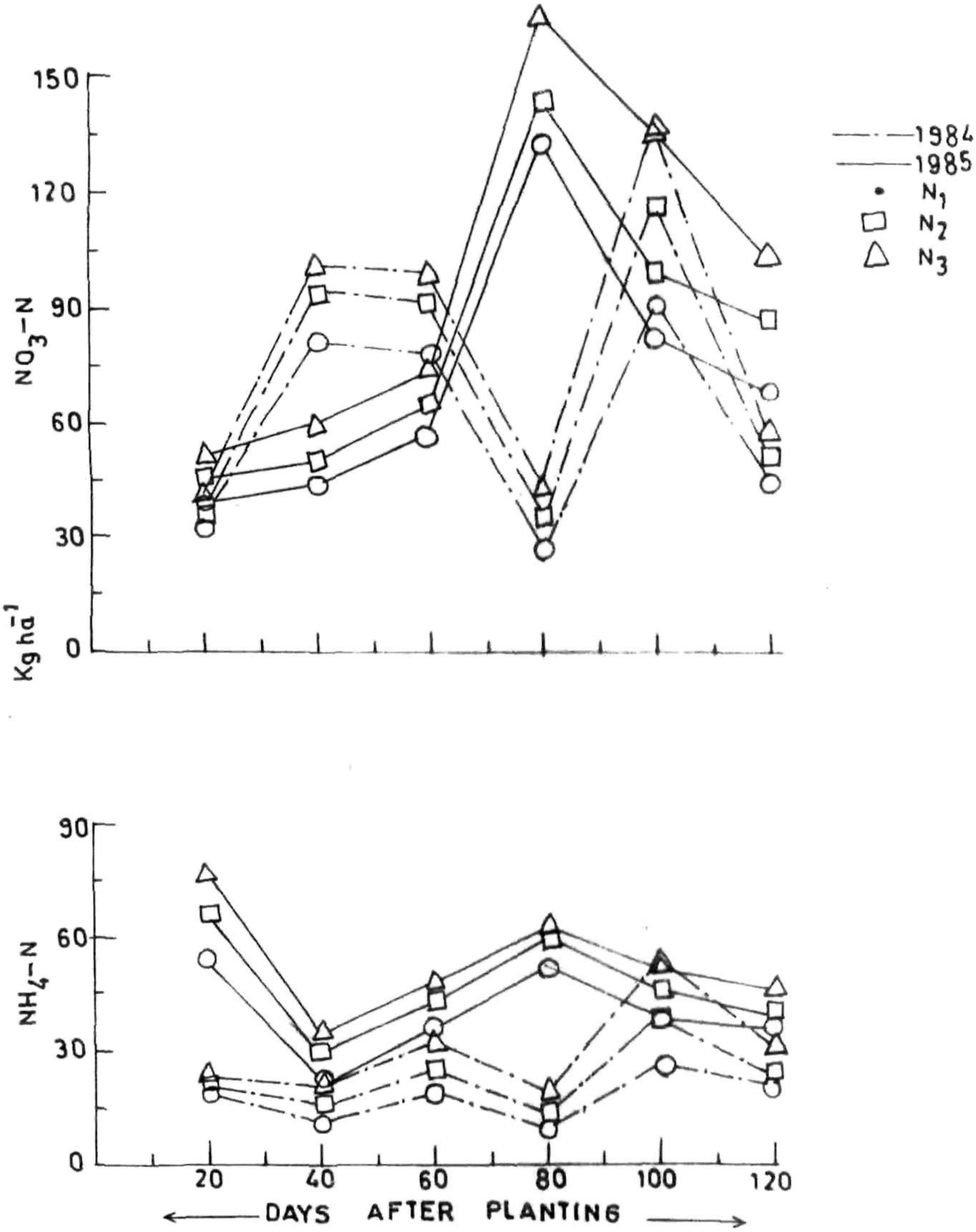

FIG. 4·1:- NO_3-N AND NH_4-N CONTENT IN SOIL AS AFFECTED BY N-APPLICATION.

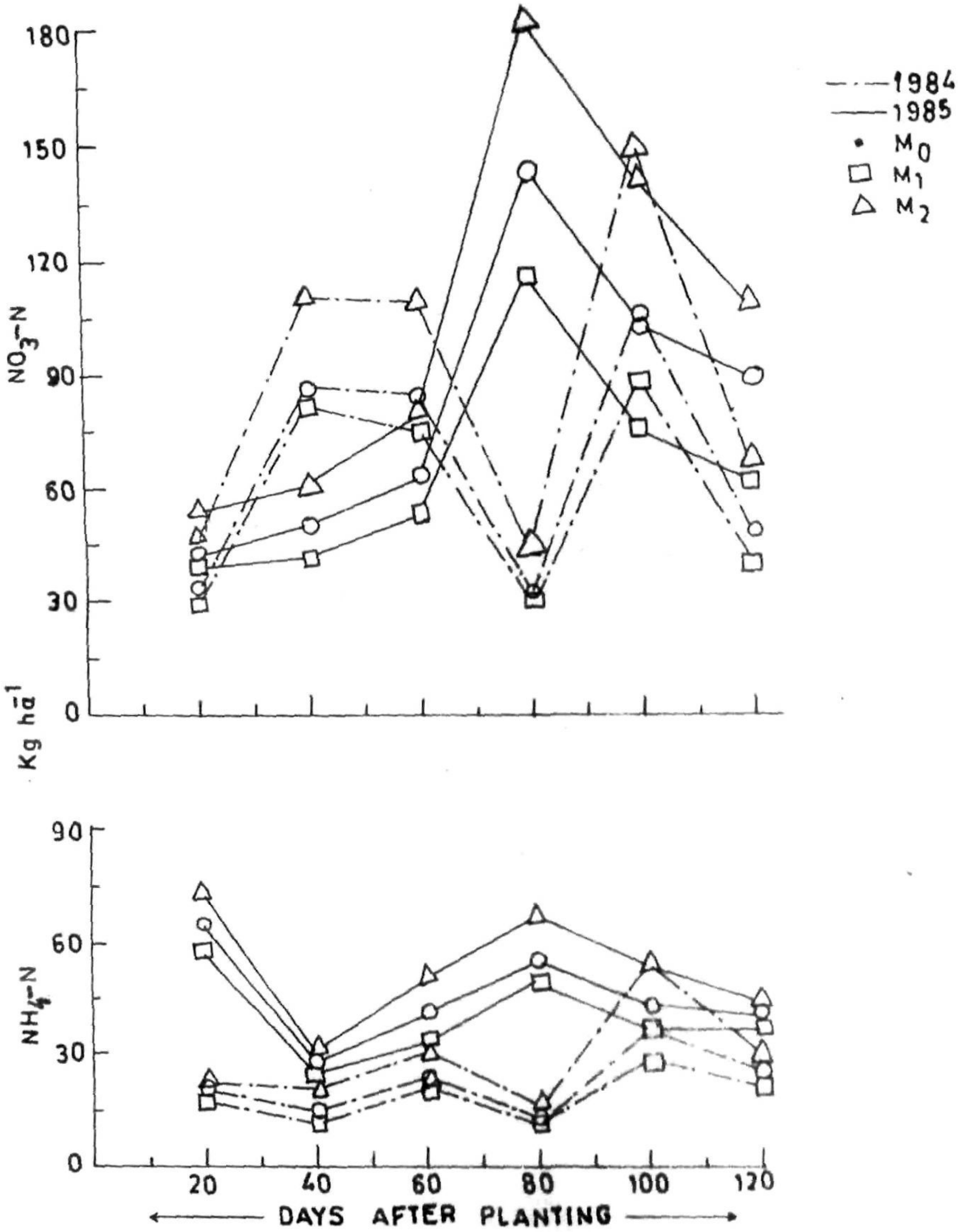

FIG 4.2:- NO_3-N & NH_4-N CONTENT IN SOIL AS AFFECTED BY ORGANIC MATTER

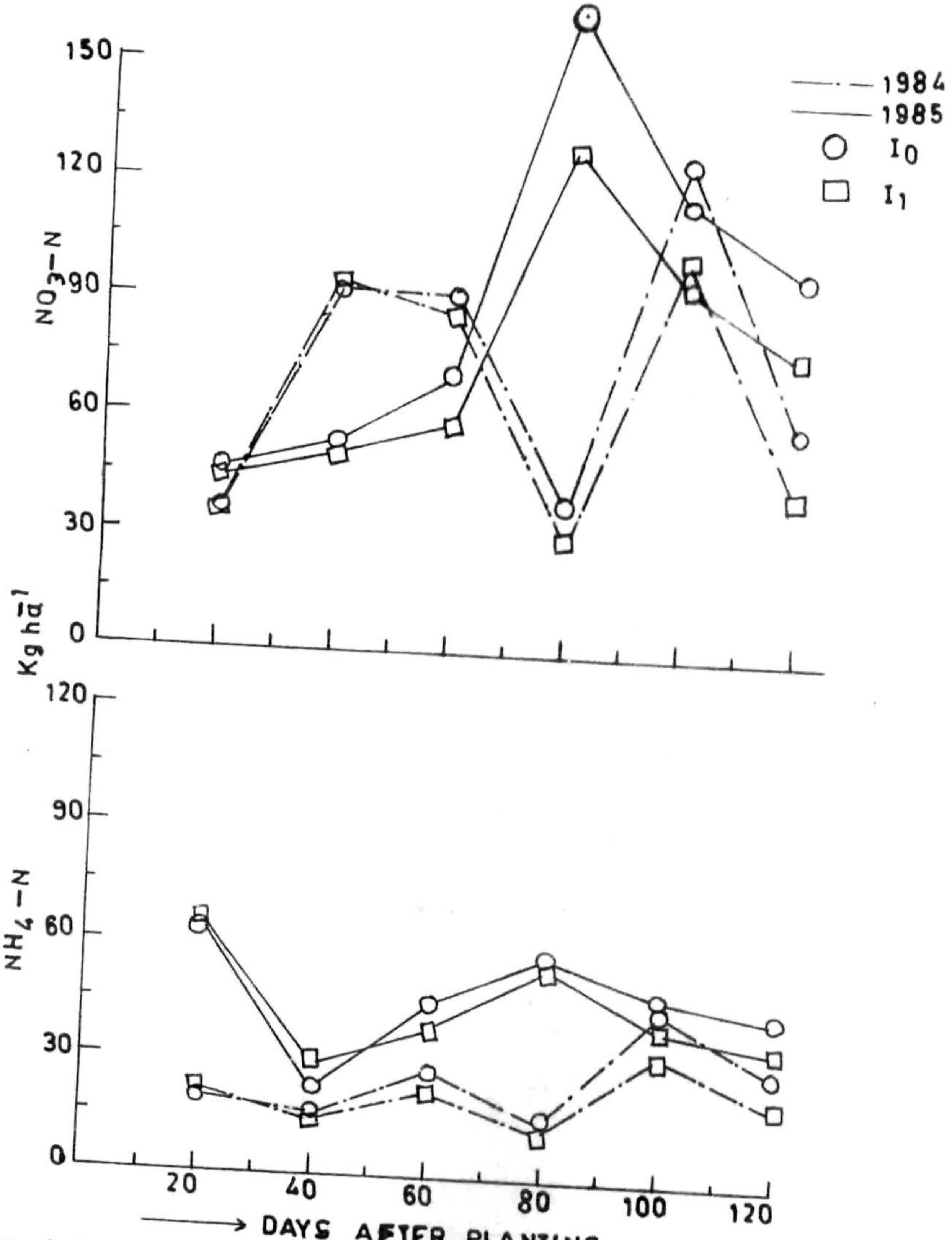

FIG.4·3:- NO_3-N & NH_4-N CONTENT IN SOIL AS AFFECTED BY IRRIGATION.

The per cent increases due to 80 kg N/ha over 40 kg N/ha during 1984 and 1985 at the time intervals of 20, 40, 60, 80, 100 and 120 days were 8.44, 13.53; 15.60, 13.11; 16.28, 12.17; 30.81, 8.20; 27.76, 21.74 and 12.54, 28.18, respectively (Table 4.1 and 4.2). Likewise the per cent increases due to 120 kg N/ha over 80 kg N/ha during the same period were of the order of 15.63, 13.21; 7.36, 19.57; 7.76, 15.36; 21.9, 14.79; 15.45, 35.57 and 13.62 and 18.35, respectively.

So far as NH_4-N content is concerned, it was comparatively more with higher rate of nitrogen application during 1984, but during 1985 both the higher application rates (N_{80} and N_{120}) had higher NH_4-N content in the soil compared to lower rate of application(Fig.4.1). The per cent increases due to 80 kg/ha N application over 40 kg N/ha during 1984 and 1985 at the time intervals of 20, 40, 60, 80, 100 and 120 days after sowing were 8.96, 20.57; 36.54, 36.42; 36.30, 20.07; 31.91, 14.59; 43.98, 19.42 and 9.77, 11.31, respectively (Tables 4.3 and 4.4). Likewise the per cent increases due to 120 kg nitrogen over 80 kg N/ha for the same time intervals during 1984 and 1985 were of the order of 10.26, 15.41; 32.86, 15.43; 32.74, 14.38; 41.47, 4.90; 39.44, 13.02 and 32.48, 16.35, respectively (Tables 4.3 and 4.4).

4.1.1.2 Effect of organic matter incorporation:

The data pertaining to the effect of organic matter incorporation on NO_3-N and NH_4-N in soils for both the years are presented graphically (Fig. 4.2). As seen from the figure, the application of farm yard manure at the rate of 10 tons/ha before planting resulted in the higher contents of both NO_3-N and NH_4-N throughout the growth period, compared to no incorporation of organic matter. The increase was significant for NO_3-N on 10.4.1984, 30.4.1984 and 20.5.1984 during first year and on 26.2.1985, 27.4.1985 and 17.5.1985 during second year as seen from the interaction between NxM (Tables 4.1.a and 4.2.a). Further, it was interesting to note from the interaction between nitrogen and organic matter that the content of NO_3-N in soil with the application of 40 and 80 kg N/ha along with FYM was either higher or at par with the contents under their respective higher levels without FYM. Therefore, a net saving of 40 kg of N/ha could be effected with the application of FYM @ 10 t/ha if the soil content of NO_3-N was any index of growth and yield of potato. The effect was more pronounced specially for NO_3-N at 40,60 and 100 days after planting in 1984 while in 1985 the effect was more at 40,60 and 80 days after planting (Fig.4.2). The comparative increases in NO_3-N and NH_4-N contents during 1985 over no incorporation were more after second dressing at 79 days after planting. The per cent increases in the contents of NO_3-N due to application of farm yard manure over no incorporation during 1984 and 1985 at 20,40,60,80,100 and 120 days after planting were 40.04, 25.78; 26.45, 21.08; 29.52, 24.83; 33.86, 26.55; 40.37, 36.35 and 37.40, 21.68,respectively (Table 4.1 and 4.2). Likewise the per cent increases in the concentrations of NH_4-N due to application of farm yard manure over no incorporation during the same period in 1984 and 1985 were of the order of 8.03, 12.01; 40.80,16.17,26.62, 25.56; 23.35, 22.00; 51.91, 28.64 and 13.68, 6.98, respectively.

Table 4.1 NO_3-N (kg/ha) in soil as influenced by different levels of nitrogen, irrigation and organic matter (1984)

Treatments	Dates of sampling					
	1.3.84	21.3.84	10.4.84	30.4.84	20.5.84	4.6.84
N_1	33.27	82.42	78.99	27.23	92.12	45.45
N_2	36.08	95.28	91.85	35.62	117.70	51.15
N_3	41.72	102.30	98.98	43.17	135.89	58.12
SE m±	1.17	1.49	1.19	1.08	1.50	1.34
C.D. at 5%	3.37	4.29	3.44	3.12	4.32	3.88
I_o	37.08	92.84	92.54	39.35	127.28	59.29
I_1	36.97	93.83	87.34	31.32	103.19	43.86
SE m±	0.95	1.21	0.97	0.99	1.22	1.10
C.D. at 5%	NS	NS	2.81	2.03	3.53	3.16
M_o	34.09	87.57	84.68	32.45	106.96	48.42
M_1	29.25	81.69	75.46	30.13	88.61	39.76
M_2	47.74	110.74	109.68	43.44	150.14	66.53
SE m±	1.17	1.49	1.19	1.08	1.50	1.34
C.D. at 5%	3.37	4.29	3.44	3.12	4.32	3.88
C.V.	13.43	6.78	5.65	13.05	5.53	11.09

NS = Non-significant.

Table 4.2 NO_3-N (kg/ha) in soil as influenced by different levels of nitrogen, irrigation and organic matter (1985)

Treatments	Dates of sampling					
	6.2. 85	26.2.85	18.3.85	7.4.85	27.4.85	17.5.85
N_1	40.28	44.53	57.48	134.35	82.83	68.76
N_2	45.73	50.37	64.48	145.38	100.84	88.14
N_3	51.73	60.23	74.39	166.89	136.71	104.32
SE m±	1.70	1.87	1.79	3.69	3.69	2.50
C.D. at 5%	4.90	5.40	5.15	10.63	10.62	7.20
I_0	46.37	52.01	71.15	166.04	118.18	97.55
I_1	45.46	51.41	59.75	131.71	95.40	76.60
SE m±	1.39	1.53	1.46	3.01	3.01	2.04
C.D. at 5%	NS	NS	4.21	8.68	8.67	5.88
M_0	43.16	50.65	63.61	145.26	103.63	89.49
M_1	40.29	43.15	53.32	117.54	75.45	62.82
M_2	54.29	61.33	79.41	183.83	141.30	108.30
SE m±	1.70	1.87	1.79	3.69	3.69	2.50
C.D. at 5%	4.90	5.40	5.15	10.63	10.62	7.20
C.V.	15.74	15.41	11.62	10.53	14.67	12.20

NS = Non-significant.

Table 4.3 NH_4-N (kg/ha) in soil as influenced by different levels of nitrogen, irrigation and organic matter (1984)

Treatments	Dates of sampling					
	1.3.84	21.3.84	10.4.84	30.4.84	20.5.84	4.6.84
N_1	18.86	11.52	19.03	10.09	26.78	21.48
N_2	20.55	15.73	24.74	13.31	38.56	23.58
N_3	22.66	20.90	32.84	18.83	53.77	31.24
SE m±	0.74	0.70	1.00	0.56	0.85	0.92
C.D. at 5%	2.14	6.51	2.89	1.61	2.46	2.66
I_0	20.28	16.48	27.94	15.36	45.61	29.20
I_1	21.10	15.62	23.13	12.80	33.80	21.66
SE m±	0.60	0.57	0.82	0.45	0.69	0.75
C.D. at 5%	NS	NS	2.36	1.31	2.01	2.16
M_0	20.79	15.00	24.53	13.23	36.25	25.64
M_1	18.82	12.02	21.03	12.69	27.79	21.51
M_2	22.46	21.12	31.06	16.32	55.07	29.15
SE m±	0.74	0.70	1.00	0.56	0.85	0.92
C.D. at 5%	2.14	6.51	2.89	1.61	2.46	2.66
C.V.	15.28	18.55	16.71	16.89	9.14	15.40

NS = Non-significant.

Table 4.4 NH_4-N (kg/ha) in soil as influenced by different levels of nitrogen, irrigation and organic matter (1985)

Treatments	Dates of sampling					
	6.2.85	26.2.85	18.3.85	7.4.85	27.4.85	17.5.85
N_1	55.20	21.80	35.86	51.79	37.96	35.71
N_2	66.56	29.74	43.06	59.35	45.36	39.75
N_3	76.82	34.33	48.22	62.26	51.27	46.25
SE m±	1.70	1.21	1.61	1.63	1.55	1.16
C.D. at 5%	4.91	3.48	4.65	4.69	4.47	3.35
I_0	65.63	22.66	45.68	59.80	47.82	44.42
I_1	66.76	29.58	39.08	55.80	41.90	36.72
SE m±	1.39	0.99	1.32	1.33	1.26	0.95
C.D. at 5%	NS	NS	3.80	3.82	3.65	2.73
M_0	65.81	27.70	41.30	55.57	42.97	41.08
M_1	59.06	25.98	33.98	50.02	36.34	36.68
M_2	73.72	32.18	51.86	67.80	55.28	43.95
SE m±	1.70	1.21	1.61	1.63	1.55	1.16
C.D. at 5%	4.91	3.48	4.65	4.69	4.47	3.35
C.V.	10.95	17.95	16.20	11.95	14.69	12.19

NS = Non-significant.

It was quite interesting to note (Fig. 4.2) that the application of *Lantana camara* resulted in the repression of both NO_3-N and NH_4-N throughout the experimental period(Table 4.1- 4.4). During 1984 the contents of both NO_3-N and NH_4-N were slightly lower than the contents under the treatment with no incorporation.However, in the year 1985, the differences in NO_3-N were more during the later part of growth period(Table 4.2). The per cent decreases in the content of NO_3-N due to application of *Lantana camara* at the rate of 10 tons per hectare compared to no incorporation at 20,40,60,80, 100 and 120 days during 1984 and 1985 were of the order of 14.19, 6.64; 6.71; 14.80; 10.88, 16.17, 7.41, 19.08; 17.15, 27.19 and 17.88, 29.80, respectively(Tables 4.1 and 4.2). Similarly the per cent decrease in NH_4-N content due to application of *Lantana camara* compared to no incorporation at the same time intervals during 1984 and 1985 were 9.47, 10.25; 19.86, 6.20; 14.26,1[illegible].72; 4.08, 9.98; 23.33, 15.42 and 16.10, 10.71 (Tables 4.3-4.4). The perusal of interaction NxM also revealed that the application of lantana, generally, resulted in the reduction of NO_3-N and NH_4-N content in soil. The reductions in NO_3-N were significant in most of the cases (Tables 4.1.a, 4.2.a and Appendix XI,XII).

4.1.1.3 Effect of Irrigation:

The data pertaining to the effect of irrigation on the NH_4-N and NO_3-N contents of soil for both the years are given in Fig.4.3.As seen from the figure, during the entire growth period the content of NO_3-N and NH_4-N, in general, was higher under rainfed treatment compared to irrigated one.The differences

Table 4.1.a NO_3-N (kg/ha) in soil as influenced by NxM (1984)

Treatments	10.4.84			30.4.84			20.5.84		
	M_o	M_1	M_2	M_o	M_1	M_2	M_o	M_1	M_2
N_1	77.43	67.36	92.20	27.96	22.12	31.61	85.02	99.54	127.80
N_2	86.08	74.96	114.51	31.12	32.97	42.78	108.35	93.51	151.26
N_3	90.52	84.07	122.35	38.27	35.31	55.93	123.52	112.77	171.38
	SE m$\pm$ = 2.07			SE m$\pm$ = 1.88			SE m$\pm$ = 2.60		
	C.D.at 5% = 5.97			C.D. at 5% = 5.41			C.D. at 5% = 7.49		

Table 4.2.a NO_3-N (kg/ha) in soil as influenced by NxM (1985)

Treatments	26.2.85			27.4.85			17.5.85		
	M_o	M_1	M_2	M_o	M_1	M_2	M_o	M_1	M_2
N_1	38.09	41.28	54.23	84.97	58.57	104.95	71.15	50.65	84.50
N_2	52.34	43.20	55.55	103.80	74.62	124.10	96.42	57.81	110.18
N_3	61.51	44.97	74.22	122.12	93.17	194.84	100.91	80.00	132.04
	SE m$\pm$ = 3.25			SE m$\pm$ = 6.39			SE m$\pm$ = 4.33		
	C.D. at 5% = 9.36			C.D. at 5% = 18.40			C.D. at 5% = 12.47		

between rainfed and irrigated treatments were more pronounced during the later part of crop growth, especially after second dressing. The per cent increases in NO_3-N under rainfed conditions over irrigated ones after 60, 80, 100 and 120 days of sowing, where differences were large due to treatments, were 5.95, 19.07; 25.63, 26.06; 23.54, 23.87 and 35.18, 27.34 during 1984 and 1985, respectively (Tables 4.1 and 4.2). Likewise, the per cent increases in NH_4-N concentration under rainfed conditions over irrigated ones during the same time intervals were 20.79, 16.88; 20.00, 7.16; 34.94, 14.12 and 34.81, 20.96 during 1984 and 1985, respectively (Tables 4.3 and 4.4).

4.1.2 Physical characteristics of soil:

4.1.2.1 Soil Water Content:

The soil water content was determined in the surface 20 cm of soil before germination and during crop growth at regular interval of seven days (Tables 4.5 and 4.6). The interactions and analysis of variance are given in appendix XIII-XVI and XXV-XXVI. As given in the tables 4.5 and 4.6, there was no significant differences in the moisture content due to nitrogen levels in both the years except on march 16th and 23rd during 1984 and on May 4th and 18th during 1985. The effect of irrigation on soil moisture content was observed to be significant after March 30th (49 days after planting) and March 2nd(42 days after planting) after first irrigation was applied during 1984 and 1985, respectively. There was marked influence on soil water content due to incorporation of FYM and lantana from planting till harvest during 1984 and after first irrigation during 1985.

Table 4.5 Soil moisture content expressed as percentage on mass basis (0-20 cm) during crop growth under different treatments(1984)

Treatments	February		March					April				May			
	17th	24th	2nd	9th	16th	23rd	30th	6th	14th	21st	28th	5th	12th	19th	26th
N_1	20.87	25.44	23.14	23.18	17.86	19.54	21.04	22.54	19.32	17.30	16.46	16.41	15.26	14.61	12.86
N_2	21.20	25.71	23.88	23.47	19.90	20.73	21.75	22.92	19.75	17.96	17.35	16.82	14.63	14.73	12.92
N_3	20.77	25.53	23.83	23.45	19.91	21.08	21.73	22.40	20.22	18.27	16.54	16.83	14.50	14.62	12.69
SE m±	0.51	0.45	0.45	0.51	0.41	0.36	0.43	0.35	0.39	0.36	0.38	0.35	0.31	0.28	0.27
C.D. at 5%	NS	NS	NS	NS	1.19	1.05	1.05	NS	NS	NS	NS	NS	NS	NS	NS
I_o	20.93	25.69	23.70	23.18	18.96	20.21	21.26	21.27	18.02	15.86	14.00	13.80	11.86	14.04	11.67
I_1	20.96	25.43	23.53	23.56	19.49	20.69	21.75	23.97	21.51	19.82	19.57	19.57	17.74	15.27	13.98
SE m±	0.41	0.37	0.37	0.41	0.33	0.29	0.35	0.29	0.32	0.29	0.31	0.29	0.25	0.23	0.22
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	0.83	0.92	0.86	0.91	0.84	0.74	0.67	0.65
M_o	19.40	24.25	21.86	21.54	15.73	17.07	19.05	22.61	18.66	16.72	15.74	15.83	13.84	13.94	11.96
M_1	21.39	25.69	23.95	23.85	20.51	21.80	22.17	22.47	20.66	18.39	16.63	17.05	15.06	14.88	13.02
M_2	22.05	26.74	25.04	24.72	21.43	22.49	23.29	22.78	19.96	18.42	17.97	17.18	15.49	15.14	13.49
SE m±	0.51	0.45	0.45	0.51	0.58	0.36	0.43	0.35	0.39	0.36	0.38	0.35	0.31	0.28	0.27
C.D. at 5%	1.47	1.30	1.32	1.47	1.68	1.05	1.25	NS	1.13	1.05	1.11	1.03	0.91	0.82	0.80
C.V.	10.36	67.53	8.24	9.30	9.14	7.59	6.63	6.70	8.49	8.72	9.84	9.12	9.08	8.33	9.22

Table 4.6 Soil moisture content expressed as percentage on mass basis (0-20 cm) during crop growth under different treatments (1985)

Treatments	February				March					April				May			
	2nd	9th	16th	23rd	2nd	9th	16th	23rd	30th	6th	13th	20th	27th	4th	11th	18th	25th
N_1	24.89	25.74	24.35	23.49	23.07	23.36	21.08	21.70	21.84	21.51	25.75	21.21	17.97	21.47	17.78	16.46	15.12
N_2	25.78	25.66	24.25	23.74	23.22	23.65	21.37	21.80	23.27	21.91	25.83	21.33	17.81	23.12	17.89	16.89	14.68
N_3	25.00	25.27	24.24	23.55	22.86	24.19	21.58	22.07	21.91	21.76	25.50	21.09	17.04	21.21	17.48	15.55	14.71
SEm±	0.34	0.37	0.36	0.32	0.33	0.58	0.34	0.53	0.80	0.57	0.28	0.36	0.46	0.37	0.40	0.29	0.32
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.08	NS	0.83	NS
I_o	24.94	25.46	24.76	23.75	23.13	22.17	20.62	21.49	21.43	19.74	25.13	21.11	16.93	16.50	14.40	14.10	12.35
I_1	25.50	25.65	23.80	23.44	22.97	25.29	22.07	22.22	23.26	23.71	26.32	21.30	18.28	27.37	21.03	18.50	17.33
SEm±	0.28	0.30	0.29	0.26	0.27	0.47	0.27	0.43	0.65	0.46	0.23	0.29	0.37	0.30	0.32	0.23	0.26
C.D. at 5%	NS	NS	1.05	NS	NS	1.66	0.79	NS	NS	1.34	0.66	NS	1.08	0.88	0.94	0.68	0.77
M_o	24.88	25.46	23.83	23.14	21.94	22.32	20.46	21.00	20.99	20.64	25.14	20.33	16.69	20.70	17.24	15.80	14.99
M_1	25.59	25.51	24.40	23.65	23.32	24.49	21.85	24.00	24.81	22.43	26.34	22.82	16.64	21.93	18.53	16.70	14.52
M_2	25.20	25.69	24.61	23.99	23.88	24.38	21.72	20.57	21.22	22.10	25.61	20.48	19.49	23.17	17.38	16.41	15.01
SEm±	0.34	0.37	0.36	0.32	0.33	0.58	0.34	0.53	0.80	0.57	0.28	0.36	0.46	0.37	0.40	0.29	0.32
C.D. at 5%	NS	NS	NS	NS	NS	1.67	0.97	1.52	2.30	NS	0.81	1.05	1.33	1.08	1.15	NS	NS
C.V.	5.87	6.27	6.40	5.76	6.15	10.37	6.76	10.29	15.20	11.19	4.65	7.31	11.15	7.31	9.63	7.59	9.42

In comparison to rainfed conditions, there was an increase in the soil water content with the application of irrigation to the tune of 12.69, 19.36, 24.96, 39.78, 41.81, 49.57, 8.76, and 19.79 per cent from 6.4.84 to 26.5.84, respectively and 14.07, 7.03, 3.39, 8.53, 20.11, 4.73, 7.97, 65.87, 46.04, 31.20 and 40.32 per cent from 9.3.85 to 13.4.85 and 27.4.85 to 25.5.85, respectively. Among the organic materials the effect of lantana on the soil moisture content was more pronounced than the FYM during the year 1985 although during 1984 both were equally effective. The significant interaction effects on soil water content are given in Appendix XIV - XVI.

4.1.2.2 Infiltration studies:

The infiltration studies were made after the harvest of the crop during both the years and the data are given on tables 4.7 and 4.8. Both the infiltration rate and the cumulative infiltration increased with the incorporation of organic matter compared to no incorporation. The average rates of infiltration were 10.46, 9.36; 8.51, 8.26 and 6.18, 6.25 cm/hr with the application of FYM, lantana and no incorporation during 1984 and 1985, respectively. Likewise the cumulative infiltration rates for three hours were 36.59, 45.12; 33.16, 40.20 and 23.94, 32.39 cm/3 hr with the application of FYM, lantana and no incorporation during 1984 and 1985, respectively. The increasing rates of nitrogen also increased the rate of infiltration. The average infiltration rates for 40,80 and 120 kg N/ha doses were 8.51, 6.93, 8.41, 8.06, and 8.60, 8.88 cm/hr during 1984 and 1985, respectively. Similarly, the cumulative rates for 3 hours with the application of 40,80 and 120 kg N/ha were 29.46, 34.94;

31.15, 38.94 and 33.07, 43.82 cm during 1984 and 1985, respectively. Irrigation resulted in reduction in the infiltration. The average values for infiltration rates during 1984 under irrigated and rainfed conditions were 7.92, 8.85 and during 1985 were 7.58, 8.33, respectively. In the same way the average values for cumulative infiltration/3 hr for irrigated and rainfed conditions during 1984 were 29.46, 33.67 and in 1985 were 36.99, 42.08 cm., respectively.

4.1.2.3 Bulk Density:

The bulk density of 0-15 cm soil layer, determined after the harvest of the crop during both the years (Tables 4.7 and 4.8) was low with the incorporation of organic matter, especially FYM (1.14 and 1.05 g/cc during 1984 and 1985, respectively). The bulk density values were also low with the increasing levels of nitrogen during both the years of study.

4.1.2.4 Organic Carbon Content:

The organic carbon content of the soil under different treatments was determined at the time of planting and at a regular interval of twenty days till the harvest of the crop (data not reported here). It was observed that neither the different doses of nitrogen nor irrigation had any effect on the organic content of the soil.However, Lantana camara and FYM applications brought out significant increases in the organic carbon content of the soil.

Table 4.7 Average values for infiltration rate, cumulative infiltration and bulk density as affected by different treatments (1984)

Treatments	Infiltration rate(cm/hr)	Cumulative Infiltration (cm/3 hrs)	Bulk density (gm/cc)
N_1	8.51	29.46	1.23
N_2	8.41	31.15	1.20
N_3	8.60	33.07	1.19
I_0	8.85	33.67	1.21
I_1	7.92	29.46	1.20
M_0	6.18	23.94	1.27
M_1	8.51	33.16	1.21
M_2	10.46	36.59	1.14

Table 4.8 Average values for infiltration rate, cumulative infiltration and bulk density as affected by different treatments (1985)

Treatments	Infiltration rate (cm/hr)	Cumulative infiltration (cm/3 hrs)	Bulk density (gm/cc)
N_1	6.93	34.94	1.12
N_2	8.06	38.94	1.10
N_3	8.88	43.82	1.09
I_0	8.33	42.08	1.11
I_1	7.58	36.39	1.09
M_0	5.25	32.39	1.14
M_1	8.26	40.20	1.11
M_3	9.36	45.12	1.05

4.2 Growth and development of Potato as affected by different treatments:

The various plant growth parameters like germination count, height, number of branches and leaflets at different stages were similar during both years of experimentation. The data are reported in tables 4.9 - 4.22 a. The analysis of variance and some of the interactions are given in appendices XXVII - XXXV and XVII - XVIII.

4.2.1 Germination Count:

Germination count during the years 1984 and 1985 after 36 and 37 days of sowing at a regular interval of four days for almost a month is given in tables 4.9 and 4.10. There was general increase in the germination with increasing levels of nitrogen, but the increase was non-significant in majority of the cases. Irrigation also increased the germination almost on all dates but the significant increase was noticed only during 1985. The application of FYM generally increased the germination of potato and the increase was significant on 17.3.84, 21.3.84, 29.3.84 and 5.4.1985. The incorporation of lantana strikingly reduced the germination of potato on all the observed dates. The per cent reduction in germination during 1984 with application of lantana compared to no incorporation was of the order of 55.69, 44.24, 19.80, 17.71, 12.08, 8.05 and 5.77 per cent on 21.3.84 through 14.4.84, respectively, and 57.7, 60.5, 52.1, 36.3, 34.9, 17.7, 9.9, 6.6 and 2.4 on 1.3.1985 through 5.4.1985, respectively. Irrigation increased the germination percentage as compared to rainfed conditions during 1984 and 1985 but the significant effect was observed only during 1985.

Table 4.9 Germination percentage of potato as influenced by different levels of nitrogen, irrigation and organic matter during 1984

Treatments	17.3.84	21.3.84	25.3.84	29.3.84	2.4.84	6.4.84	10.4.84	14.4.84
N_1	1.26 (1.58)	3.86 (14.89)	6.72 (45.15)	8.00 (64.00)	8.40 (70.56)	8.82 (77.79)	9.02 (81.36)	9.41 (88.54)
N_2	1.25 (1.56)	4.03 (16.24)	6.66 (44.35)	8.38 (70.22)	8.71 (75.86)	9.08 (82.44)	9.27 (85.93)	9.28 (86.11)
N_3	1.22 (1.48)	4.08 (16.64)	7.04 (49.56)	8.34 (69.55)	8.85 (78.32)	9.17 (84.08)	9.37 (87.79)	9.42 (88.73)
SE m±	0.02	0.26	0.22	0.22	0.20	0.11	0.10	0.09
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
I_o	1.25 (1.56)	4.02 (16.16)	6.76 (45.69)	8.18 (66.91)	8.64 (74.64)	8.91 (79.38)	9.14 (83.53)	9.33 (87.04)
I_1	1.23	3.96	6.90	8.30	8.66	9.14	9.31	9.41
SE m±	0.02	0.21	0.19	0.18	0.16	0.09	0.08	0.07
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
M_o	1.00 (1.00)	4.78 (22.84)	7.91 (62.56)	8.33 (69.38)	9.09 (82.62)	9.35 (87.42)	9.43 (88.92)	9.52 (90.63)
M_1	1.36 (1.84)	1.64 (2.68)	4.41 (19.44)	6.68 (44.62)	7.48 (55.95)	8.22 (67.56)	8.67 (75.16)	8.97 (80.46)
M_2	1.37 (1.87)	5.55 (30.82)	8.10 (65.61)	9.20 (84.64)	9.38 (87.98)	9.50 (90.25)	9.56 (91.39)	9.62 (92.54)
SE m±	0.02	0.26	0.22	0.22	0.20	0.11	0.10	0.09
C.D. at 5%	0.07	0.75	0.65	0.63	0.58	0.32	0.30	0.27
C.V.	9.44	27.82	14.12	11.45	9.99	5.31	4.93	4.19

The values given in parenthesis are theoriginal values.

Data analysed by using $\sqrt{x}$ transformation.

Table 4.10 Germination percentage of potato as influenced by different levels of nitrogen, irrigation ar organic matter during 1985

Treatments	1.3.85	5.3.85	9.3.85	13.3.85	17.3.85	21.3.85	25.3.85	29.3.85	5.4.85
N_1	2.67 (7.12)	4.44 (19.71)	5.33 (28.40)	6.15 (37.82)	7.34 (53.87)	8.43 (71.06)	8.95 (80.10)	9.34 (87.23)	9.49 (90.06)
N_2	2.70 (7.29)	4.70 (22.09)	5.55 (30.80)	6.60 (43.56)	7.53 (56.70)	8.50 (72.25)	9.00 (81.00)	9.23 (85.19)	9.48 (89.87)
N_3	2.85 (8.12)	4.81 (23.13)	5.58 (31.13)	6.72 (45.15)	7.87 (61.93)	8.52 (72.59)	8.84 (78.14)	9.42 (88.73)	9.57 (91.58)
SE m±	0.14	0.15	0.12	0.14	0.07	0.07	0.13	0.05	0.02
C.D. at 5%	NS	NS	NS	0.42	0.20	NS	NS	0.14	0.07
I_0	2.82 (7.95)	4.46 (19.89)	5.41 (29.26)	6.60 (43.56)	7.50 (56.25)	8.33 (69.38)	8.83 (77.96)	9.20 (84.64)	9.48 (89.87)
I_1	2.66 (7.07)	4.84 (23.42)	9.56 (91.39)	6.38 (40.70)	7.70 (59.29)	8.64 (74.64)	9.03 (81.54)	9.46 (89.49)	9.55 (91.20)
SE m±	0.11	0.12	0.09	0.11	0.05	0.06	0.11	0.04	0.02
C.D. at 5%	NS	0.36	0.28	NS	0.16	0.18	NS	0.12	0.05
M_0	3.21 (10.30)	5.67 (32.14)	6.52 (42.51)	7.27 (52.85)	8.56 (73.27)	8.94 (79.92)	9.21 (84.82)	9.52 (90.63)	9.56 (91.39)
M_1	1.49 (2.22)	2.24 (5.01)	3.12 (9.73)	4.63 (21.43)	5.57 (31.02)	7.36 (54.16)	8.30 (68.89)	8.89 (79.03)	9.33 (87.03)
M_2	3.52 (12.39)	6.04 (36.48)	6.81 (46.37)	7.58 (57.45)	8.66 (74.99)	9.15 (83.72)	9.28 (86.11)	9.57 (91.58)	9.79 (95.84)
SE m±	0.14	0.15	0.12	0.14	0.07	0.07	0.13	0.05	0.02
C.D. at 5%	0.41	0.45	0.34	0.42	0.20	0.22	0.40	0.14	0.07
C.V.	22.49	14.32	9.32	9.55	3.93	3.84	6.65	2.24	1.08

The values given in parenthesis are the original values.

Data analysed by using $\sqrt{x}$ transformation.

4.2.2 Height of Potato:

The data on height (tables 4.11 - 4.14) are given only from 5.4.84 to 5.5.84 and 13.3.85 to 22.4.85 at a regular interval of ten days because no differences in height beyond these dates were observed and same have not been recorded here. There were significant differences in height due to various treatments all through the observed period. The maximum height was recorded with the treatment having incorporation of FYM and receiving 120 kg N/ha under irrigated conditions during both the years (Tables 4.11 and 4.12). It was closely followed by the treatment receiving 80 kg N/ha along with FYM under irrigated conditions. The height was significantly higher under this treatment on 13.3.85 compared to other treatments and also so during rest of the period upto 22.4.1985 except under treatment receiving FYM along with 80 kg N/ha under irrigated conditions. The lowest height was recorded with the application of lantana under rainfed conditions with the application of 40 kg N/ha during both the years of experimentation.

There was a significant effect of the levels of nitrogen on the height of plants all through the observed growth period during 1984 and 1985(Tables 4.13 and 4.14). For instance, the application of 80 kg N resulted in an increase of height by 16.32, 16.76, 16.62, and 7.52% over 40 kg N/ha on 5.4.84,15.4.84, 25.4.84 and 5.5.84, respectively, and 16.58, 13.63, 18.86,20.14 and 12.25 per cent over 40 kg N/ha on 13.3.85, 23.3.85, 2.4.85, 12.4.85 and 22.4.85,respectively.Likewise, the application of 120 kg N/ha resulted in an increase of height by 8.61, 10.15, 8.08 and 8.22 per cent over 80 kg N/ha on 5.4.84 through 5.5.84 and 30.55

Table 4.11 Average height (cm) of potato as affected by different treatments during 1984

Treatments			5.4.84	15.4.84	25.4.84	5.5.84
N_1	M_o	I_o	8.00	15.33	20.33	25.00
		I_1	9.00	21.00	28.00	32.00
	M_1	I_o	7.33	14.00	18.00	24.00
		I_1	8.00	20.00	25.00	30.00
	M_2	I_o	9.00	17.00	24.00	29.00
		I_1	12.00	24.00	33.00	37.00
N_2	M_o	I_o	9.00	18.00	24.00	26.00
		I_1	11.00	24.00	32.00	34.00
	M_1	I_o	8.00	16.00	21.00	25.33
		I_1	10.00	23.00	29.00	34.00
	M_2	I_o	11.00	21.00	29.00	33.00
		I_1	13.00	28.00	38.00	38.00
N_2	M_o	I_o	10.00	20.00	26.00	29.00
		I_1	11.33	26.00	35.00	37.00
	M_1	I_o	9.00	17.00	23.00	28.00
		I_1	11.00	25.00	31.00	36.00
	M_2	I_o	12.00	24.16	31.33	32.00
		I_1	14.00	31.00	41.00	44.00
SE m$\pm$			0.57	1.05	1.34	2.04
C.D. at 5%			1.66	3.03	3.87	5.87
C.V.			9.87	8.55	8.27	11.18

Table 4.12 Average height (cm) of potato as affected by different treatments during 1985

Treatments			13.3.85	23.3.85	2.4.85	12.4.85	22.4.35
N_1	M_o	I_o	7.00	13.00	17.00	20.00	23.66
		I_1	8.00	19.00	24.00	28.00	31.16
	M_1	I_o	6.00	12.33	14.66	19.00	22.50
		I_1	8.50	17.00	23.00	27.00	30.00
	M_2	I_o	7.50	15.00	21.00	26.00	32.33
		I_1	9.50	24.00	29.50	34.00	41.00
N_2	M_o	I_o	8.00	15.00	21.00	25.00	26.00
		I_1	9.50	21.00	29.00	34.00	35.00
	M_1	I_o	7.50	13.00	18.00	24.00	25.83
		I_1	9.00	18.00	25.00	33.00	34.00
	M_2	I_o	8.50	18.00	24.50	28.00	37.00
		I_1	11.50	29.00	36.00	41.00	45.00
N_3	M_o	I_o	10.00	18.00	24.50	27.00	30.00
		I_1	12.50	23.00	32.00	39.00	40.00
	M_1	I_o	9.50	15.00	20.00	28.00	30.33
		I_1	12.00	20.00	31.66	36.00	38.00
	M_2	I_o	11.50	21.00	25.00	33.00	40.00
		I_1	15.00	31.00	39.00	45.00	46.83
SE m±			0.59	1.19	1.36	1.57	1.58
C.D. at 5%			1.71	3.42	3.93	4.53	2.21
C.V.			10.88	10.54	9.38	8.99	8.09

Table 4.13 Average height (cm) of potato as influenced by different levels of nitrogen, irrigation and organic matter during 1984

Treatments	5.4.84	15.4.84	25.4.84	5.5.84
N_1	8.88	18.55	24.72	29.50
N_2	10.33	21.66	28.83	31.72
N_3	11.22	23.86	31.16	34.33
SE m±	0.23	0.43	0.55	0.69
C.D. at 5%	0.67	1.23	1.58	2.39
I_0	9.25	18.05	24.03	27.92
I_1	11.03	24.66	32.44	35.33
SE m±	0.19	0.35	0.44	0.68
C.D. at 5%	0.55	1.01	1.29	1.95
M_0	9.72	20.72	27.55	30.50
M_1	8.88	19.16	24.50	29.55
M_2	11.83	24.19	32.66	34.83
SE m±	0.23	0.43	0.55	0.69
C.D. at 5%	0.67	1.23	1.58	2.39
C.V.	9.87	8.55	8.27	11.18

Table 4.14 Average height (cm) of potato plant as influenced by different levels of nitrogen, irrigation and organic matter during 1985

Treatments	13.3.85	23.3.85	2.4.84	12.4.85	22.4.85
N_1	7.72	16.72	21.52	25.66	30.11
N_2	9.00	19.00	25.58	30.83	33.80
N_3	11.75	21.33	28.69	34.66	37.52
SE m$\pm$	0.24	0.48	0.55	0.64	0.64
C.D. at 5%	0.70	1.39	1.60	1.85	1.85
I_o	8.38	15.59	20.62	25.55	29.74
I_1	10.62	22.44	29.90	35.22	37.88
SE m$\pm$	0.19	0.39	0.45	0.52	0.27
C.D. at 5%	0.57	1.14	1.31	1.52	1.51
M_o	9.16	18.16	24.58	28.83	30.97
M_1	8.75	15.88	22.05	27.83	30.11
M_2	10.58	23.00	29.16	34.50	40.36
SE m$\pm$	0.24	0.48	0.55	0.64	0.64
C.D. at 5%	0.70	1.39	1.60	1.85	1.85
C.V.	10.88	10.54	9.38	8.99	8.09

Table 4.14 a Average height (cm) of potato as influenced by IxM (1985)

Treatments	23.3.85	
	I_0	I_1
M_0	15.33	21.00
M_1	13.44	18.33
M_2	18.00	28.00

SE m$\pm$ = 0.68

C.D. at 5% = 1.97

12.26, 12.15, 12.42 and 11.00 per cent on 13.3.85 through 22.4.85, respectively. The effect of irrigation was quite notable in increasing the height of plants significantly during both the years. The increase in height due to irrigation was 19.24, 36.62, 34.99 and 26.54 per cent over rainfed conditions on 5.4.84, 15.4.84, 25.4.84 and 5.5.84, respectively and 26.73, 43.93, 45.00, 37.84 and 27.37 per cent over rainfed conditions on 13.3.85, 23.3.85, 2.4.85, 12.4.85 and 22.4.85, respectively. The application of FYM significantly increased the height of plants at all stages but reverse was true with the application of lantana. The significant negative influence of application of lantana was observed on 5.4.84, 15.4.84 and 25.4.84, and 23.3.85 and 2.4.85. The per cent increases in the height due to application of FYM were 21.70, 16.74, 18.54 and 14.19 compared to no incorporation on 5.4.84, 15.4.84, 25.4.84 and 5.5.84, respectively, and 15.50, 26.65, 18.63, 19.66 and 30.31% compared to no incorporation on 13.3.85, 23.3.85, 2.4.85, 12.4.85 and 22.4.85, respectively.

The interaction between irrigation and organic matter incorporation (table 4.14 a) was only significant on 23.3.85. Both under rainfed and irrigated conditions FYM @ 10 t/ha (M_2) produced significantly more height than lantana application and no incorporation (M_1 and M_o) but the differences between M_o and M_1 were not significant under rainfed conditions. However, the differences between each pair of treatments during the year 1985 were significant under irrigated conditions, the mean height being minimum under M_1 and maximum under M_2.

4.2.3 Number of branches per plant:

As seen from the data given in table 4.15, the effect of the highest level of N along with the incorporation of FYM under irrigated conditions on the development of branches was not of higher order as seen for other growth parameters. The number of branches under this treatment generally did not differ significantly from other treatments receiving lower levels of nitrogen during 1984 and 1985. The effect of nitrogen application (tables 4.17 and 4.18) on the development of branches was significant only upto 80 kg N/ha during 1984 and 1985 beyond which the increase was non-significant except on 22.4.85. The application of irrigation significantly increased the number of branches compared to rainfed conditions during both the years of experimentation. The per cent increases in the number of branches due to irrigation were 15.45, 12.36, 11.77, 9.40 and 10.22 on 13.3.85, 23.3.85, 2.4.85, 12.4.85 and 22.4.85, respectively. The application of FYM resulted in significant increase in the number of branches over no incorporation except on 5.4.84 and 12.4.85 when the increase was non-significant. The per cent increases due to application of FYM over no incorporation were 8.95, 11.41, 10.77 and 11.11 on dates 5.4.84, 15.4.84, 25.4.84 and 5.5.84, respectively, and 7.83, 10.83, 8.83,11.90 and 9.95 per cent on dates 13.3.85, 23.3.85, 2.4.85, 12.4.85 and 22.4.85, respectively. The application of lantana brought about a decrease in the number of branches compared to no incorporation and the decrease was significant only on 13.3.85 and 23.3.85. The per cent decreases on these dates were 18.58 and 10.31, respectively. During 1984, the per cent decreases

Table 4.15 Average number of branches per plant of potato as affected by different treatments during 1984

Treatments			5.4.84	15.4.84	25.4.84	5.5.84
N_1	M_o	I_o	9.00	12.00	14.00	14.33
		I_1	12.00	14.33	14.66	14.66
	M_1	I_o	9.66	11.33	12.66	13.00
		I_1	10.66	13.66	14.66	14.86
	M_2	I_o	11.33	14.00	15.33	15.50
		I_1	12.00	15.00	16.00	16.33
N_2	M_o	I_o	12.00	13.66	14.00	14.60
		I_1	12.33	15.00	16.00	16.00
	M_1	I_o	11.33	14.20	14.33	14.66
		I_1	12.00	14.33	15.00	15.33
	M_2	I_o	12.33	15.00	16.66	17.00
		I_1	14.00	16.66	17.00	17.66
N_3	M_o	I_o	12.00	14.00	14.33	14.50
		I_1	13.00	15.66	17.00	17.29
	M_1	I_o	12.00	13.66	14.33	14.66
		I_1	12.66	13.00	15.66	16.06
	M_2	I_o	13.33	15.33	16.00	16.35
		I_1	13.66	18.00	18.33	18.60
SE m±			1.07	1.05	0.88	0.75
C.D. at 5%			NS	3.04	2.55	2.16
C.V.			15.56	13.35	10.03	8.33

Table 4.16 Average number of branches per plant of potato as affected by different treatments during 1985

Treatments			13.3.85	23.3.85	2.4.85	12.4.85	22.4.85
N_1	M_o	I_o	10.00	12.00	13.00	13.66	14.60
		I_1	12.00	12.00	15.00	15.33	16.33
	M_1	I_o	8.00	11.00	13.00	14.66	15.00
		I_1	9.00	12.00	15.00	17.00	17.33
	M_2	I_o	10.00	13.00	14.33	16.00	16.66
		I_1	11.00	14.00	16.66	18.33	19.00
N_2	M_o	I_o	11.00	12.00	14.33	16.00	16.66
		I_1	13.00	15.66	17.00	17.00	18.00
	M_1	I_o	9.33	11.00	13.00	14.33	14.66
		I_1	11.00	13.00	15.66	16.33	16.66
	M_2	I_o	13.00	16.00	16.33	17.33	17.66
		I_1	15.00	16.00	17.00	18.00	18.66
N_3	M_o	I_1	12.00	13.33	16.00	16.33	17.66
		I_1	13.00	15.33	15.00	17.00	18.00
	M_1	I_o	10.00	11.00	15.00	17.00	18.00
		I_1	11.33	14.00	15.00	15.33	16.00
	M_2	I_o	13.33	14.33	15.00	18.00	18.66
		I_1	15.33	15.66	19.00	19.00	20.00
SE m$\pm$			0.74	0.67	0.67	0.56	0.46
C.D. at 5%			2.13	1.95	1.94	1.62	1.33
C.V.			11.12	8.78	7.65	5.92	4.67

Table 4.17 Average number of branches per plant of potato as influenced by different levels of nitrogen, irrigation and organic matter

Treatments	5.4.84	15.4.84	25.4.84	5.5.84
N_1	10.77	13.44	14.50	14.75
N_2	12.38	14.77	15.50	15.87
N_3	12.77	14.88	15.94	16.23
SE m±	0.43	0.45	0.36	0.30
C.D. at 5%	0.67	NS	1.04	0.88
I_o	11.48	13.62	14.62	14.95
I_1	12.48	15.11	16.00	16.29
SE m±	0.35	0.36	0.29	0.25
C.D. at 5%	NS	1.06	0.85	0.72
M_o	11.72	14.11	14.94	15.21
M_1	11.44	13.27	14.44	14.75
M_2	12.77	15.72	16.55	16.90
SE m±	0.43	0.45	0.36	0.30
C.D. at 5%	NS	1.30	1.04	0.88
C.V.	15.56	13.35	10.03	8.33

Table 4.18 Average number of branches per plant of potato as influenced by different levels of nitrogen, irrigation and organic matter during 1985

Treatments	13.3.85	23.3.85	2.4.85	12.4.85	22.4.85
N_1	10.00	12.33	14.50	15.83	16.50
N_2	12.22	13.94	15.55	16.50	17.05
N_3	12.50	13.94	15.83	17.11	17.94
SE m±	0.30	0.27	0.33	0.23	0.18
C.D. at 5%	0.87	0.79	0.95	0.66	0.54
I_o	10.74	12.62	14.44	15.74	16.33
I_1	12.40	14.18	16.14	17.22	18.00
SE m±	0.24	0.22	0.26	0.18	0.15
C.D. at 5%	0.71	0.65	0.77	0.54	0.44
M_o	12.00	13.38	15.05	15.88	16.77
M_1	9.77	12.00	14.44	15.77	16.27
M_2	12.94	14.83	16.38	17.77	18.44
SE m±	0.30	0.27	0.33	0.23	0.18
C.D. at 5%	0.87	0.79	0.95	NS	0.54
C.V.	11.12	8.78	7.65	5.92	4.67

Table 4.18 a Average number of branches per plant of potato as influenced by NxM (1985)

Treatments	12.4.85			22.4.85		
	M_0	M_1	M_2	M_0	M_1	M_2
N_1	14.50	15.83	17.16	15.50	16.16	17.83
N_2	16.50	15.33	17.66	17.33	15.66	18.16
N_3	16.66	16.16	18.50	17.50	17.00	19.33
	SE m±	=	0.39	SE m±	=	0.32
	C.D. at 5%	=	1.14	C.D. at 5%	=	0.94

due to lantana application compared to no incorporation were 2.38, 5.95, 3.34 and 3.02 on dates 5.4.84, 15.4.84, 25.4.84 and 5.5.84, respectively but the differences were not significant.

The favourable effect of the application of FYM along with nitrogen is also evident from the interaction between nitrogen levels and organic matter incorporation (Table 4.18 a) as the number of branches in general was significantly higher with the application of FYM at all nitrogen levels compared to no incorporation.

4.2.4 Number of leaflets per plant:

The highest number of leaflets per plant were observed under treatment having incorporation of FYM and receiving 120 kg N/ha under irrigated conditions throughout the observed growth period during 1984 and 1985(Tables 4.19 and 4.20). This treatment was followed closely by treatment having incorporation of FYM and receiving 80 kg N/ha under irrigated conditions and treatment receiving 120 kg N/ha along with FYM under rainfed conditions during both years of experimentation.

There was an increase in the number of leaflets per plant with the increasing levels of nitrogen (Tables 4.21 and 4.22) and significant increases were observed on 5.4.84, 15.4.84, 25.4.84, 5.5.84 and 2.4.85, 12.4.85 and 22.4.85 due to application of 80 kg N/ha compared to 40 kg N/ha and all through the observed growth period with the application of 120 kg N/ha compared to 80 kg N/ha during 1984 and 1985,respectively. The per cent increases due to application of 80 kg N/ha compared to 40 kg N/ha on 5.4.84, 15.4.84, 25.4.84 and 5.5.84

were 13.12, 15.18, 17.79 and 18.33 and on dates 13.5.85,23.5.85 2,4,85, 12.4.85 and 22.4.85 were 4.33, 6.96, 11.20, 13.81 and 17.62, respectively. The per cent increases due to application of 120 kg N/ha over 80 kg N/ha were 9.04, 12.66, 16.57 and 18.28 on 5.4.84, 15.4.84, 25.4.84 and 5.5.84, respectively. The per cent increases due to application of 120 kg N/ha over 80 kg N/ha were 5.76, 12.39, 15.38, 17.58 and 13.47 on 13.3.85, 23.3.85, 2.4.85, 12.4.85 and 22.4.85, respectively. Irrigation resulted in significant increase in the number of leaflets per plant throughout the observed growth period during 1984 and 1985. The per cent increases on 5.4.84, 15.4.84, 25.4.84 and 5.5.84 were 10.75, 17.10, 21.62 and 21.25, respectively, and on 13.3.85, 23.3.85, 2.4.85, 12.4.85 and 22.4.85 were 10.75, 15.69, 20.92, 23.06 and 23.42, respectively. The application of FYM made a significant increase in the number of leaflets per plant compared to no incorporation on all the dates. The increases on 5.4.84, 15.4.84, 25.4.84 and 5.5.84 were 17.30, 19.49, 19.27 and 21.21 and on 13.3.85, 23.3.85, 2.4.85, 12.4.85 and 22.4.85 were 23.01, 24.70, 24.71, 27.36 and 26.10 per cent, respectively. The application of lantana resulted in significant decrease in the number of leaflets per plant on all the dates during 1984 but during 1985 the differences between M_o and M_1 were non-significant.

The favourable effect of application of FYM alongwith increasing levels of nitrogen on number of leaflets is strikingly evident from the interaction between nitrogen levels and organic matter incorporation during 1985(Table 4.22 a), as the application of FYM along with nitrogen resulted in significant

Table 4.19 Average number of leaflets per plant of potato as affected by different treatments during 1984

Treatments			5.4.84	15.4.84	25.4.84	5.5.84
N_1	M_o	I_o	74.00	91.66	113.00	114.0
		I_1	84.00	109.00	142.33	143.00
	M_1	I_o	69.33	74.33	91.00	97.00
		I_1	81.66	103.00	129.00	134.00
	M_2	I_o	89.00	112.00	136.00	141.00
		I_1	97.00	127.00	165.66	169.00
N_2	M_o	I_o	89.00	106.33	133.66	137.00
		I_1	95.00	120.00	159.00	163.00
	M_1	I_o	77.00	96.00	119.00	121.33
		I_1	83.00	113.00	149.66	158.00
	M_2	I_o	99.00	124.33	157.00	163.00
		I_1	117.00	151.00	197.00	202.00
N_3	M_o	I_o	99.00	123.66	163.66	166.00
		I_1	98.66	135.00	179.00	187.00
	M_1	I_o	85.00	113.00	148.66	159.00
		I_1	97.00	124.00	169.00	177.00
	M_2	I_o	109.00	139.00	183.00	194.00
		I_1	122.66	165.00	223.66	234.00
SE m$\pm$			4.93	4.81	5.87	5.55
C.D. at 5%			14.19	13.86	16.91	15.97
C.V.			9.23	7.06	6.64	6.05

Table 4.20 Average number of leaflets per plant of potato as affected by different treatments during 1985

Treatments			13.3.85	23.3.85	2.4.85	12.4.85	22.4.85
N_1	M_o	I_o	80.33	98.00	119.00	134.00	135.00
		I_1	91.66	115.00	145.66	165.00	167.00
	M_1	I_o	74.33	89.66	109.33	122.66	126.00
		I_1	87.00	108.66	135.33	154.66	162.00
	M_2	I_o	95.00	116.66	142.00	162.00	163.00
		I_1	103.66	133.00	172.66	203.00	206.00
N_2	M_o	I_o	86.66	107.00	132.33	152.00	160.00
		I_1	85.00	112.00	151.00	178.66	190.00
	M_1	I_o	79.66	100.33	126.66	147.00	155.00
		I_1	87.66	114.00	151.33	177.00	186.00
	M_2	I_o	103.00	126.00	159.00	184.66	193.00
		I_1	113.00	147.00	196.00	232.00	244.00
N_3	M_o	I_o	82.33	106.33	139.66	163.00	170.00
		I_1	97.00	132.33	178.33	211.00	216.00
	M_1	I_o	81.33	109.00	146.00	172.00	173.00
		I_1	97.66	134.00	183.00	217.00	218.00
	M_2	I_o	111.66	149.00	192.33	229.86	232.00
		I_1	117.00	164.00	218.00	267.00	271.00
SE m±			3.78	6.76	8.06	4.87	4.45
C.D. at 5%			10.69	19.47	23.18	14.01	12.79
C.V.			6.92	9.75	8.98	4.64	4.11

Table 4.21 Average number of leaflets per plant of potato as influenced by different levels of nitrogen, irrigation and organic matter during 1984

Treatments	5.4.84	15.4.84	25.4.84	5.5.84
N_1	82.50	102.83	129.50	133.00
N_2	93.33	118.44	152.55	157.38
N_3	101.77	133.44	177.83	186.16
SE m$\pm$	2.01	1.96	2.40	2.26
C.D. at 5%	5.79	5.65	6.90	6.51
I_o	87.81	108.92	138.33	143.59
I_1	97.25	127.55	168.25	174.11
SE m$\pm$	1.64	1.60	1.95	1.85
C.D. at 5%	4.73	4.62	5.63	5.32
M_o	89.94	114.27	148.44	151.66
M_1	82.16	103.88	134.38	141.05
M_2	105.50	136.55	177.05	183.83
SE m$\pm$	2.01	1.96	2.40	2.26
C.D. at 5%	5.79	5.65	6.90	6.51
C.V.	9.23	13.86	25.91	6.05

Table 4.22 Average number of leaflets per plant of potato as influenced by different levels of nitrogen, irrigation and organic matter during 1985

Treatments	13.3.85	23.3.85	2.4.85	12.4.85	22.4.85
N_1	88.66	110.16	137.33	156.88	159.83
N_2	92.50	117.83	152.72	178.55	188.00
N_3	97.83	132.44	176.22	209.94	213.33
SE m±	1.51	2.74	3.29	1.98	1.81
C.D. at 5%	4.36	7.94	9.46	5.71	5.22
I_o	88.25	111.40	140.70	163.00	167.44
I_1	97.74	128.88	170.14	200.59	206.66
SE m±	1.23	2.22	2.68	1.62	1.48
C.D. at 5%	3.56	6.49	7.72	4.67	4.26
M_o	87.16	111.77	144.33	167.27	173.00
M_1	84.61	109.27	141.94	165.05	170.00
M_2	107.22	139.38	180.00	213.05	218.16
SE m±	1.51	2.74	3.29	1.98	1.81
C.D. at 5%	4.36	7.94	9.46	5.71	5.22
C.V.	6.92	9.75	8.98	4.64	4.11

Table 4.22 a Average number of leaflets per plant of potato as influenced by MxN (1985)

Treatments	12.4.85			22.4.85		
	M_o	M_1	M_2	M_o	M_1	M_2
N_1	149.50	138.66	182.50	151.00	144.00	184.50
N_2	165.33	162.00	208.33	175.00	170.50	218.50
N_3	187.00	194.50	248.33	193.00	195.50	251.50

	SE m± = 3.44	SE m± = 3.14
	C.D. at 5% = 9.90	C.D. at 5% = 9.04

increase in number of leaflets compared to the same when nitrogen was applied alone. The application of lantana along with nitrogen generally decreased the number of leaflets compared to application of nitrogen alone.

4.2.5 Tuber size:

The pooled data for the years 1984 and 1985 on small, medium and large grades of potato, expressed as percentage of total yield in a particular treatment are given in Tables 4.23 and 4.24. The data given in table 4.23 revealed that the highest percentage (34.15) of small grade potato was in the treatment which received 120 kg N/ha along with lantana under irrigated conditions. It was closely followed (28.42%) by the treatment receiving 40 kg N/ha together with lantana under rainfed conditions. The lowest percentage (10.64) of small grade potato was observed in the treatment receiving 120 kg N/ha together with FYM under irrigated conditions.

Similarly, the highest percentage (47.03) of medium size tubers resulted in the treatment which received 40 kg N/ha in combination with lantana under rainfed conditions closely followed by (46.98%) the treatment receiving 120 kg N/ha with lantana under rainfed conditions. The lowest percentage (30.54) of medium size tubers was obtained in the treatment which received 120 kg N with FYM under irrigated conditions. However, different treatment combinations under medium grade potato was found to be non-significant one.

Likewise, in 120 kg N/ha with FYM treatment under irrigated conditions recorded the highest percentage (58.82%) of large grade potato tubers followed by the treatment receiving

80 kg N/ha along with FYM under irrigated conditions. The lowest percentage (21.79) of large grade tubers was in the treatment which received 120 kg N/ha in combination with lantana under irrigated conditions. The perusal of data indicated that the increasing levels of nitrogen did not have any significant effect on the small and medium grade potatoes but the effect was significant on the production of large grade potatoes upto 80 kg N/ha(Table 4.24). The proportion of large grade potato with the application of 120 kg nitrogen was at par with that of 40 kg N/ha. The irrigation also influenced significantly the proportion of small and large grade potatoes. With the application of irrigation the proportion of small grade potatoes was significantly low and that of large grade potatoes significantly high compared to rainfed treatment. With the incorporation of FYM, again, the proportion of small grade potato was significantly low and that of large grade potatoes significantly higher compared to no incorporation. The FYM application also decreased the proportion of medium size potatoes but the decrease was not significant. The incorporation of lantana significantly increased the proportion of small grade potatoes and decreased significantly that of large grade potato, compared to no incorporation.

The IxM interactions of small and large grade potatoes (Table 4.24 a and 4.24 b) revealed that with the application of FYM, there was reduction in the proportion of small grade potatoes and increase in large grade potatoes over no incorporation both under rainfed and irrigated conditions but the significant

Table 4.23 Per cent tuber size distribution as affected by different treatments (pooled yield for 1984 and 1985)

Treatments			Small	Medium	Large
N_1	M_o	I_o	25.10	42.59	32.31
		I_1	16.07	39.11	44.82
	M_1	I_o	28.42	47.03	24.55
		I_1	26.05	45.29	28.66
	M_2	I_o	18.93	41.21	39.86
		I_1	12.52	41.19	46.29
N_2	M_o	I_o	20.99	42.29	36.72
		I_1	19.33	36.38	44.29
	M_1	I_o	23.31	31.20	45.49
		I_1	25.92	39.09	34.99
	M_2	I_o	14.33	40.97	44.70
		I_1	14.35	32.62	53.03
N_3	M_o	I_o	20.83	40.06	39.11
		I_1	13.39	39.33	47.28
	M_1	I_o	25.06	46.98	27.96
		I_1	34.15	44.06	21.79
	M_2	I_o	24.82	37.40	37.76
		I_1	10.64	30.54	58.82
SE m±			2.18	3.93	3.75
C.D. at 5%			6.27	NS	10.80
C.V.			18.18	17.11	16.53

Table 4.24 Tuber size distribution as affected by different levels of nitrogen, irrigation and organic matter (the values are percentages of pooled yield for 1984 and 1985)

Treatments	Small	Medium	Large
N_1	21.18	42.73	36.08
N_2	19.70	37.09	43.20
N_3	21.48	39.72	38.79
SE m±	0.89	1.60	1.53
C.D. at 5%	NS	NS	4.41
I_o	22.42	41.08	36.49
I_1	19.16	38.62	42.21
SE m±	0.72	1.31	1.25
C.D. at 5%	2.09	NS	3.60
M_o	19.28	39.96	40.75
M_1	27.15	42.27	30.57
M_2	15.93	37.32	46.74
SE m±	0.89	1.60	1.53
C.D. at 5%	2.56	NS	4.41
C.V.	18.18	17.11	16.53

Table 4.24 a Small grade of potato as influenced by IxM (the values are percentages of pooled yield for 1984 and 1985

Treatments	I_o	I_1
M_o	22.31	16.26
M_1	25.59	28.71
M_2	19.36	12.50
SE m$\pm$ =	1.26	
C.D. at 5%=	3.62	

Table 4.24 b Large grade of potato as influenced by IxM interaction(the values are percentages of pooled yield for 1984 and 1985)

Treatments	I_o	I_1
M_o	36.04	45.46
M_1	32.66	28.48
M_2	40.78	52.71
SE m$\pm$ =	2.16	
C.D. at 5%=	6.24	

effect for the same was found only under irrigated conditions. The incorporation of lantana, unlike FYM, caused increases and decreases in the proportions of small and large grade potatoes, respectively, over no incorporation of organic matter both under rainfed and irrigated conditions but the significant effect for the same was found only under irrigated conditions.

4.3 Tuber and haulm yield as affected by different treatments

4.3.1 Tuber yield:

The data given in table 4.25 reveal that the highest tuber yields of 196.46 and 253.31 q/ha were obtained in the treatment receiving irrigation and 120 kg of nitrogen along with FYM @ 10 t/ha during 1984 and 1985, respectively. This was followed by the treatment receiving irrigation and 80 kg N/ha along with FYM. The lowest yield was recorded under rainfed conditions in the treatment receiving 40 kg of nitrogen along with application of lantana @ 10 t/ha. In general, treatments receiving irrigation, FYM and higher doses of nitrogen were having higher yield. The analyses of variance and some interactions are given in appendices XXXVI - XXXVII.

4.3.1.1 Effect of nitrogen:

The increasing rates of nitrogen upto 120 kg/ha resulted in significant increase in tuber yield during 1985 (Table 4.26). However, the increase in tuber yield beyond 80 kg N/ha was not significant during 1984. The per cent increases in tuber yield due to application of 80 kg N/ha over 40 kg N and 120 kg N/ha over 80 kg N were 15.81 and 22.93 during 1985, respectively (Table 4.26).

Table 4.25 Potato tuber yield (q/ha) as affected by different treatments during 1984 and 1985

Treatments	1984	1985	Pooled
$N_1M_oI_o$	37.19	49.70	43.44
$N_1M_oI_1$	93.32	95.12	94.22
$N_1M_1I_o$	38.24	39.84	39.04
$N_1M_1I_1$	79.58	82.16	80.87
$N_1M_2I_o$	52.63	71.54	62.09
$N_1M_2I_1$	125.69	154.21	139.95
$N_2M_oI_o$	45.60	59.91	52.76
$N_2M_oI_1$	140.27	104.40	122.33
$N_2M_1I_o$	53.88	43.34	48.61
$N_2M_1I_1$	107.77	92.97	100.36
$N_2M_2I_o$	73.58	102.45	88.01
$N_2M_2I_1$	174.80	167.37	171.08
$N_3M_oI_o$	52.38	81.15	66.76
$N_3M_oI_1$	145.38	109.31	127.34
$N_3M_1I_o$	57.44	44.85	51.14
$N_3M_1I_1$	122.50	97.24	109.87
$N_3M_2I_o$	76.11	115.36	95.73
$N_3M_2I_1$	196.46	253.31	224.89
SE m$\pm$	10.57	4.23	7.26
C.D. at 5%	30.42	12.19	20.90
C.V.	19.71	7.49	13.25

Table 4.26 Potato tuber yield (q/ha) as influenced by different levels of nitrogen, irrigation and organic matter during 1984 and 1985

Treatments	1984	1985	Pooled yield
N_1	71.11	82.09	76.60
N_2	99.32	95.07	97.13
N_3	108.38	116.87	112.62
SE m±	4.31	1.73	2.72
C.D. at 5%	12.41	4.97	7.84
I_o	54.12	67.57	60.84
I_1	131.75	128.45	130.10
SE m±	3.52	1.41	2.22
C.D. at 5%	10.14	4.06	6.40
M_o	85.69	83.26	84.47
M_1	76.57	66.73	71.65
M_2	116.54	144.04	130.29
SE m±	4.31	1.73	2.72
C.D. at 5%	12.41	4.97	7.84
C.V.	19.71	7.49	12.11

4.3.1.2 Effect of irrigation:

Irrigation significantly increased the tuber yield compared with rainfed conditions. The yield in the former was almost double than the latter (Table 4.26). Thus, the effect of irrigation on increase in the tuber yield was more conspicuous compared to application of either nitrogen or FYM.

4.3.1.3 Effect of organic matter:

The effect of FYM on tuber yield was significant during both the years (Table 4.26). The per cent increases due to application of FYM over no incorporation was 36.00 and 73.00 during 1984 and 1985, respectively. Unlike FYM, the application of lantana resulted in significant reduction in tuber yield during 1985. The reduction was, however, not significant during 1984. However, the application of lantana under irrigated conditions resulted in depression of the tuber yield compared to no incorporation in both the years and the differences were generally high. The per cent reductions in yield due to application of lantana compared to no incorporation was 10.64 and 19.85 during 1984 and 1985, respectively.

4.3.1.4 Effect of different interactions between nitrogen levels, irrigation and organic matter on potato tuber yield:

As we see from the interaction table 4.26 a, the increasing rates of nitrogen helped in increasing the tuber yields both under rainfed and irrigated conditions and the increase due to nitrogen levels was significant upto 120 kg N/ha during 1985. The interaction between nitrogen and irrigation levels indicated that during 1985, the yield of potato increased significantly with increasing levels of nitrogen both under rainfed and irrigated conditions (Table 4.26 a). During 1984, the significant increase was not consistent but 120 kg N/ha was significantly superior to 40 kg N/ha both under irrigated and rainfed conditions. However, the yields during both the years under irrigated conditions were almost double at all the levels of nitrogen application compared to rainfed situations.

The interaction between organic matter and irrigation levels during 1984 and 1985 (Table 4.26 b) showed that there was a significant effect of application of FYM over no incorporation on the yield of potato both under rainfed and irrigated conditions. The increase in tuber yield was almost double with the irrigation compared to rainfed conditions when FYM was applied in both the years of experimentation i.e. 1984 and 1985. The per cent increases in yield over no incorporation was of the order of 33.18 and 23.24 in 1984 and 34.06 and 26.18 in 1985 under rainfed and irrigated conditions,respectively. The interaction between organic matter and irrigation further revealed that the application of lantana brought about reduction in the tuber yield both under rainfed and irrigated conditions compared to no incorporation. The significant reduction due to lantana over no incorporation was found under irrigated conditions during 1984 and 1985, but under rainfed conditions there was significant reduction during 1985 and the yield was at par during 1984. Also, as we see the interaction between nitrogen levels and organic matter during 1985(Table 4.26 c) the dose of 40 kg nitrogen along with FYM was significantly better than

Table 4.26 a Potato tuber yield (q/ha) as influenced by NxI interaction

Treatments	1984		1985		Pooled	
	I_o	I_1	I_o	I_1	I_o	I_1
N_1	42.69	99.53	53.69	110.50	48.19	105.01
N_2	57.69	140.95	68.57	121.58	63.13	131.26
N_3	61.97	154.78	80.45	153.29	71.21	154.03
	SE m$\pm$	= 6.10	SE m$\pm$	= 1.74	SE m$\pm$	= 3.85
	C.D. at 5%	=17.56	C.D. at 5%	= 5.01	C.D. at 5%	=11.09

Table 4.26 b Potato tuber yield (q/ha) as influenced by IxM interaction

Treatments	1984		1985		Pooled	
	I_o	I_1	I_o	I_1	I_o	I_1
M_o	45.06	126.32	63.59	102.94	54.32	114.63
M_1	49.85	103.28	42.67	90.79	46.76	97.03
M_2	67.44	165.65	96.45	191.63	81.94	178.64
	SE m$\pm$	= 6.10	SE m$\pm$	= 1.74	SE m$\pm$	= 3.85
	C.D. at 5%	=17.56	C.D. at 5%	= 5.01	C.D. at 5%	=11.09

Table 4.26 c Potato tuber yield (q/ha) as influenced by NxM interaction

Treatments	1985			Pooled		
	M_o	M_1	M_2	M_o	M_1	M_2
N_1	72.41	61.00	112.88	68.83	59.95	101.02
N_2	82.15	68.15	134.91	87.54	74.49	129.55
N_3	95.23	71.04	184.34	97.05	80.50	160.31
	SE m$\pm$ =		2.13	SE m$\pm$ =		4.72
	C.D. at 5% =		6.14	C.D. at 5% =		13.58

Table 4.26 d Potato tuber yield (q/ha) as influenced by NxIxM interaction (1985)

Treatments	1985			Pooled		
	M_o	M_1	M_2	M_o	M_1	M_2
N_1	49.70	39.84	71.54	95.12	82.16	154.21
N_2	59.91	43.34	102.45	104.40	92.97	167.37
N_3	81.15	44.85	115.36	109.31	97.24	253.51
	SE m$\pm$ =		4.23			
	C.D. at 5% =		12.19			

120 kg N/ha alone. This showed the application of FYM @ 10 t/ha could substitute considerable amount of inorganic nitrogen. The effect of FYM application in effecting the inorganic N saving was also alike during 1984 (Appendix XIX) but the interaction between nitrogen levels and organic matter was not significant. The treatment receiving lantana along with 40,80 and 120 kg N/ha showed significant reduction in tuber yield over 40,80 and 120 kg N/ha alone. The per cent reductions due to lantana along with 40,80 and 120 kg N/ha over the respective N doses alone were of the order of 15.75, 17.04 and 25.40, respectively, during 1985.

The interaction, NxIxM was not significant during 1984 (Appendix XX). However, on the basis of significant interaction for one year i.e. 1985 (Table 4.26 d), it was observed that the yield under rainfed conditions with the application of 80 kg N/ha along with FYM was significantly higher than with the application of 120 kg N alone. This apparently showed that with the application of FYMunder rainfed conditions there was substitution of inorganic N equivalent to 40 kg N/ha. The substitution under irrigated conditions was also of the same magnitude.

4.3.2 Haulm yield:

The haulm yield expressed on dry weight basis(Table 4.27) was observed to be the maximum with the treatment receiving 120 kg N/ha along with FYM @ 10 t/ha under irrigated conditions. The lowest yield was with the application of 40 kg N/ha along with lantana under rainfed condition. The analysis of variance is given in appendix XXXVII.

4.3.2.1 Effect of N:

The haulm yield increased significantly with the increasing levels of nitrogen as seen from the individual years data (Table 4.28). The haulm yield increased by 5.01, 4.91 and 5.30 per cent with the application of 80 kg N/ha over 40 kg N during 1984, 1985 and on pooled basis. Similarly the yield increase was of the order of 12.35, 18.33 and 14.98 per cent with the application of 120 kg N/ha over 80 kg N/ha.

4.3.2.2 Effect of irrigation:

Irrigation also brought about a significant increase in the production of dry matter compared to rainfed treatment (Table 4.28) during both the years of experimentation. As seen from 1984, 1985 and pooled yield data, the increase in haulm yield with irrigation were 8.65, 8.95 and 9.01 per cent over rainfed treatment, respectively.

4.3.2.3 Effect of organic matter:

The application of FYM increased significantly the haulm yield compared to no incorporation during both years of experimentation (Table 4.28). The per cent increase in haulm yield due to application of FYM @ 10 t/ha over no incorporation was of the order of 10.88, 14.73 and 12.81 in the year 1984, 1985 and pooled yield data, respectively. The application of lantana @ 10 t/ha, however, unlike FYM caused a significant reduction in the haulm yield during 1984. The per cent reduction due to lantana @ 10 t/ha over no incorporation during 1984, 1985 and pooled yield data was of the order of 6.85, 3.78 and 5.00, respectively.

Table 4.27: Dry matter weight (q/ha) of haulms as affected by different treatments during 1984 and 1985

Treatments			1984	1985	Pooled
N_1	M_0	I_0	15.38	15.63	15.50
		I_1	16.10	16.29	16.19
	M_1	I_0	14.96	14.51	14.73
		I_1	16.02	15.82	15.92
	M_2	I_0	16.93	17.47	17.20
		I_1	18.68	19.15	18.91
N_2	M_0	I_0	15.29	15.21	15.25
		I_1	18.40	18.12	18.26
	M_1	I_0	15.71	15.68	15.70
		I_1	16.01	16.10	16.38
	M_2	I_0	18.54	18.31	18.42
		I_1	19.04	20.31	19.67
N_3	M_0	I_0	18.18	19.12	18.64
		I_1	20.82	20.26	20.54
	M_1	I_0	16.21	18.76	17.48
		I_1	18.12	19.82	18.97
	M_2	I_0	20.59	21.04	20.81
		I_1	21.74	23.79	22.76
SE m±			0.56	0.61	0.42
C.D. at 5%			1.62	1.78	1.23
C.V.			5.57	5.93	4.16

Table 4.28: Dry matter weight (q/ha) of haulm of potato as influenced by different levels of nitrogen, irrigation and organic matter during 1984 and 1985

Treatments	1984	1985	Pooled
N_1	16.34	16.48	16.41
N_2	17.16	17.29	17.28
N_3	19.28	20.46	19.87
SE m±	0.23	0.25	0.17
C.D. at 5%	0.66	0.72	0.50
I_0	16.86	17.30	17.08
I_1	18.32	18.85	18.62
SE m±	0.18	0.20	0.14
C.D. at 5%	0.54	0.59	0.41
M_0	17.36	17.44	17.40
M_1	16.17	16.78	16.53
M_2	19.25	20.01	19.63
SE m±	0.23	0.25	0.17
C.D. at 5%	0.66	0.72	0.50
C.V.	5.57	5.93	4.16

4.3.3 Response of potato to N application (Response Curve):

The maximum response of potato in terms of tuber and haulm yield was obtained with the application of 120 kg N/ha along with FYM@ 10 t/ha under irrigated conditions. The response curve was drawn by fitting tuber yield data on to quadratic type of equation. The derived regression equation was as under:

$$Y = 131.40813 - 0.694993\ x + 0.00706905\ x^2$$

where,

Y = Potato yield (q/ha)

X = Fertilizer nitrogen rate (kg/ha)

The quadratic equations signifies that with the application of increasing rates of nitrogen, the yield of potato increased at increasing rate. As such, there was a linear response of potato to N upto a level of 120 kg N/ha. The optimum dose could be worked out by trying still higher rates of nitrogen, than tried in the present investigation.

4.4.1 Starch content in Potato tuber:

The data pertaining to starch content of potato tubers for 1984 and 1985 are given in tables 4.29 and 4.30 and the analysis of variance is given in appendix XXXVIII. During the year 1984 the highest starch content of 78.57 per cent was found in the treatment under rainfed condition receiving 40 kg of nitrogen/ha having no incorporation of organic matter, closely followed by treatment with 40 kg N/ha application with lantana under rainfed conditions (Table 4.29).

The least starch content of 61.42 per cent was obtained with the treatment under irrigated conditions receiving 120 kg N/ha along with 10 t FYM/ha. In the second year i.e. 1985, the starch content in potato due to different treatments also followed almost the same trend as in 1984. The maximum starch content (88.42%) was found under the treatment with no incorporation of organic matter under rainfed conditions with the N dose of 40 kg/ha followed by the treatment with lantana incorporation under rainfed conditions with the same dose of N (78.97%). In general, there was a decrease in the starch content with the increasing doses of N and the minimum starch content of 53.19 per cent was noted in the treatment with 120 kg N/ha application and with the incorporations of FYM @ 10 t/ha under irrigated conditions.

There was a decrease in starch content with the increasing rates of nitrogen during both the years. The applica of 120 kg N/ha significantly reduced the starch content compare to 40 and 80 kg N application rates during 1984. But during 198 the reduction was significant with each increment in N dose (Table 4.30).

As seen from table 4.30, the irrigation treatment significantly lowered starch content compared to the rainfed situation during both the years. The incorporation of FYM did not bring out any significant difference in the starch content during 1984 but during 1985, there was a significant reduction in the same.

4.4.2 Reducing sugars:

The data concerning reducing sugars in potato for both the years are given in tables 4.29 and 4.30. The analysis of variance is given in appendix XXXVIII. The highest contents of reducing sugar i.e. 1.76 and 1.78 per cent (Table 4.29) were recorded with the treatment under rainfed condition receiving 40 kg N/ha with no incorporation of organic matter during 1984 and 1985, respectively. This treatment was followed closely by the treatment under irrigated condition receiving 40 kg N/ha and no incorporation of organic matter and the treatment under rainfed conditions receiving 40 kg N/ha and having application of lantana during 1984 and 1985,respectively. The minimum reducing sugar content was recorded with the treatment under irrigated conditions receiving 120 kg N/ha along with application of farm yard manure during 1984 and with lantana during 1984 and 1985, respectively.However, the contents of reducing sugar due to different treatments did not differ significantly during the year 1984 although the differences were significant during 1985.

The increasing rates of nitrogen affected a decrease in the content of reducing sugar (Table 4.30). The application of 120 kg N/ha caused a significant reduction in the reducing sugar content compared to lower rates of application of 40 and 80 kg N/ha during 1984. During 1985 the application of 80 and 120 kg N/ha brought out significant reduction in the reducing sugar content compared to the 40 kg N/ha. The application rates of 80 and 120 kg N/ha did not have any significant difference in the reducing sugar content.

The perusal of the data for the main effects(table 4.30) showed no significant differences due to the treatment of irrigation during 1984 although the irrigation significantly reduced the reducing sugar content compared to rainfed one during the year 1985. The incorporation of organic matter did not have any significant difference in the reducing sugar content during either of the years although both the organic materials brought about a decrease in the reducing sugar content as compared to control.

4.4.3 Non-reducing sugar:

The data on the non-reducing sugar content in potato are given in tables 4.29 and 4.30. The analysis of variance is given in appendix XXXVIII. The content of non-reducing sugars due to different treatments differed significantly in 1984 as well as 1985. The highest non-reducing sugar content of 2.41 and 2.31 per cent was observed with the treatment under rainfed conditions receiving 40 kg N/ha and having no incorporation of organic matter during 1984 and 1985, respectively. This treatment was followed closely by the treatment under also rainfed conditions having no incorporation of organic matter and receiving 80 kg N/ha during 1984 and the treatment under irrigation receiving 40 kg N/ha and no incorporation of organic matter during 1985. The least non-reducing sugar content was obtained under irrigated treatment receiving 80 kg N/ha and having application of farm yard manure.

A look at the main effects (Table 4.30) revealed that the increasing rates of nitrogen also caused reduction in the non-reducing sugar content in potato. The reduction was significant with 120 kg N/ha compared to 40 kg N/ha during 1984, whereas during 1985 the significant reduction was noticed even at the 80 kg N/ha compared to 40 kg N/ha. A significant reduction in the non-reducing sugar content due to irrigation was observed during both the years. The application of organic matter also affected significant reduction in the non-reducing sugar content.

Table 4.29 Per cent starch, reducing and non-reducing sugar content in potato as affected by different treatments during 1984 and 1985

Treatments			Starch content (%)		Reducing sugar (%)		Non-reducing sugar (%)	
			1984	1985	1984	1985	1984	1985
N_1	M_o	I_o	78.57	88.42	1.76	1.78	2.41	2.31
		I_1	68.31	72.22	1.66	1.62	2.11	2.13
	M_1	I_o	76.27	78.97	1.62	1.71	2.18	2.05
		I_1	74.79	77.75	1.54	1.65	1.99	2.04
	M_2	I_o	75.33	75.11	1.50	1.66	2.00	2.01
		I_1	72.62	68.98	1.44	1.33	1.69	1.89
N_2	M_o	I_o	76.14	70.19	1.65	1.64	2.23	2.00
		I_1	67.90	67.16	1.53	1.39	2.07	1.81
	M_1	I_o	71.00	73.71	1.50	1.60	2.10	1.95
		I_1	70.19	72.22	1.39	1.31	1.87	1.90
	M_2	I_o	73.03	69.11	1.42	1.58	2.11	1.59
		I_1	67.49	67.90	1.31	1.26	1.36	1.25
N_3	M_o	I_o	67.96	58.25	1.43	1.51	2.16	1.90
		I_1	65.20	65.06	1.29	1.29	1.92	1.57
	M_1	I_o	66.68	62.77	1.39	1.45	1.87	1.73
		I_1	63.85	60.21	1.31	1.20	1.59	1.48
	M_2	I_o	66.48	56.29	1.33	1.38	1.91	1.79
		I_1	61.42	53.19	1.25	1.24	1.87	1.28
SE m±			3.46	3.04	0.12	0.12	0.11	0.19
C.D. at 5%			9.96	8.74	NS	0.35	0.31	0.54
C.V.			8.55	7.65	13.41	14.34	9.62	18.25

Table 4.30 Per cent starch, reducing sugar and non-reducing sugar content in potato as influenced by nitrogen, irrigation and organic matter during 1984 and 1985

Treatments	Starch content (%)		Reducing sugar (%)		Non-reducing sugar (%)	
	1984	1985	1984	1985	1984	1985
N_1	74.31	76.91	1.59	1.62	2.06	2.07
N_2	70.96	70.05	1.47	1.46	1.95	1.75
N_3	65.26	59.29	1.33	1.34	1.88	1.62
SE m$\pm$	1.41	1.24	0.05	0.05	0.04	0.07
C.D. at 5%	4.06	3.57	0.14	0.14	0.12	0.22
I_o	72.38	70.31	1.51	1.59	2.10	1.92
I_1	67.97	67.19	1.41	1.36	1.83	1.70
SE m$\pm$	1.15	1.01	0.04	0.04	0.03	0.06
C.D. at 5%	3.32	2.91	NS	0.11	0.10	0.18
M_o	70.46	70.22	1.55	1.53	2.15	1.95
M_1	69.39	70.94	1.46	1.49	1.93	1.86
M_2	70.68	65.10	1.38	1.40	1.82	1.63
SE m$\pm$	1.41	1.24	0.05	0.05	0.04	0.07
C.D. at 5%	NS	3.57	NS	NS	0.12	0.22
C.V.	8.72	7.65	14.82	14.34	9.62	18.25

DISCUSSION

5. DISCUSSION

Potato responds quite favourably to nitrogenous fertilizers in acid soils of the wet temperate zone of Himachal Pradesh where the soils are generally low to medium in nitrogen status. The incorporation of organic matter in the soils would enhance nutrient and water use efficiency and improve the physical environment of soil. There is growing interest among the researchers to explore the possibility for substitution of existing sources of organic matter with obnoxious weeds like Lantana camara. The results pertaining to the effect of nitrogen levels, type of organic matter and irrigation on physico-chemical characteristics of soils, growth, development, yield and quality of potato are discussed as under:

5.1 Soil characteristics as affected by different treatments.

5.1.1 NO_3-N and NH_4-N content.

5.1.1.1 NO_3-N and NH_4-N content as affected by N-fertilization:

The content of NO_3-N in soils increased slowly after nitrogen application at planting upto 40 days during 1984 and 20-60 days after planting in 1985. Thereafter there was a significant rise in the NO_3 content till 80 days after planting. The NH_4-N content remained almost constant till 40 days and increased slowly thereafter till 60 days during 1984 but in 1985 a constant increase in NH_4-N from 40 to 80 days after planting was observed (Fig. 4.1), during 1985. The NO_3-N content of the soil has been reported to increase gradually with incubation time with the application of Urea-N by Broadbent et al.(1958). Acevedo and Pereira (1964), Sattar (1975) and Singh and Grewal (1983).

Gibson (1930), Broadbent et al.(1958), Court et al. (1962), Soulides and Clark (1958) and Volk and Sweat ~~et al.~~ (1955) have shown that time necessary for complete hydrolysis of Urea varied from less than one day to three weeks or more depending upon the conditions under which it took place. According to Sinha and Prasad (1967) most of the transformations of Urea-N to NH_4-N and NO_3-N in acid soil occurred in 3rd or 4th week at all levels of application. The comparatively low NO_3-N contents during the initial period after application in this study could be ascribed largely to the prevailing low soil temperatures and wet season when the microbial activity is supposed to be quite low. It is only after the Urease activity that the applied Urea-N would get transformed to ammonia. The low soil temperatures have been reported to affect adversely the hydrolysis of urea and the ammonification/nitrification capacity of the soils (Gasser, 1964; Simpson and Melsted, 1963; Broadbent et al., 1958; Couturier and Perrand ~~et al.~~, 1925; Fisher and Parks , 1958; Littauer, 1925 and Thiagalingam and Kanihiro (1973). The slowing down of the conversion of added nitrogen to nitrates may also be due to the development of soil environment becoming too acid for the nitrifying bacteria to function actively. The concentration of NO_3-N and NH_4-N also increased after second dressing for sometime and thereafter declined with time.

The concentrations of both NO_3-N and NH_4-N (Tables 4.1 - 4.4) increased with increasing rates of fertilizer nitrogen. The increase during both the years was generally significant with increasing levels of nitrogen. The NO_3-N content of the soil has been reported to increase gradually with increasing rates of nitrogen application by Broadbent *et al.*(1958), Acevedo and Pereira (1964), Sattar (1975) and Singh and Grewal (1983). Similarly, the NH_4-N is reported to increase with time upto one or two weeks after application (Court *et al.*, 1962 and Sattar, 1975). The comparatively more concentrations of NO_3-N and NH_4-N during certain periods of crop growth due to 80 and 120 kg N/ha compared to 40 kg N/ha were probably due to higher amounts of Urea-N getting hydrolysed at higher rates during these periods. The higher amounts of Urea-N would obviously result into higher concentrations of NH_4-N and NO_3-N as suggested by Laidler and Hoare (1955) that the ammonification rate of Urea increased linearly with concentration. Sinha and Prasad (1967) also reported that, generally, higher rates of urea application increased both hydrolysis and nitrification which was in close agreement with the findings of Fisher and Parks(1958). The varying concentrations of NH_4-N and NO_3-N with time, however, were probably due to various complex phenomena operating in soils in response to varied soil and climatic factors (Krantz *et al.*, 1943).

5.1.1.2 NO_3-N and NH_4-N concentration as affected by organic matter incorporation

The application of FYM @ 10 tons/ha before sowing resulted in higher concentration of both NO_3-N and NH_4-N compared to no incorporation throughout the growth period (Table 4.1 - 4.4). The increase was especially more pronounced, with significant effect for NO_3-N, with the advancement of crop growth. The higher concentrations of NO_3-N and NH_4-N in soils with the application of farm yard manure are quite obvious as the applied nitrogen would be initially complexed by various organic compounds in FYM and would be released eventually with time. The application of FYM would also considerably reduce the leaching losses of mobile nitrates from the surface depths. Sommers et al.(1979) have highlighted the importance of organic compounds in cutting down the leaching losses of nitrogen as essentially no nitrate leaching occurred in soils receiving sewage sludge. The release of the immobilized nitrogen by organic compounds, eventually, would depend upon a number of soil and climatic factors.

The higher N utilization by potatoes with the combined application of FYM and nitrogen source compared to nitrogen source alone has been reported by Sharma et al.(1980) on acid hill soils of Shimla. In another study with potato on the same soil, Sharma (1986) reported improvement in NO_3 status of the soil with the application of FYM for three years. Zameck (1966) reported that the formation of NO_3-N was 13 per cent higher in the plots receiving manure than in plots which received mineral fertilizers. Zameck (1967) also found that the application of 40 tons FYM/ha every two years plus basal NPK increased the NO_3-N in comparison with plots receiving

NPK only. Lepnev (1967) observed the greatest NO_3 accumulation in soils when dung plus NPK was applied. Giddens and Rao (1975) indicated that incorporation of manure in the soil greatly increased the amount of NO_3-N in soil. Kumar and Singh (1984) reported that with the application of FYM along with fertilizer nitrogen a saving of 40 kg N/ha could be effected in the maize-wheat cropping sequence. FYM increased the nitrogen use efficiency of both the crops. In our study, it looks that the application of FYM would aid release of comparatively more nitrogen in our soils with the elapse of few weeks after sowing when the soil temperatures go up. The persistent higher concentrations of nitrates with application of FYM, especially, during the active growth period of crop would result into enhancement of N-use efficiency by the crop. Besides, the faster mineralization of organic nitrogen in FYM with the rise in soil temperature would also contribute to the higher nitrate contents in soils compared to no incorporation. The faster mineralization of organic nitrogen with the rise in soil temperature from 5-40^{o}C has also been reported by Thiagalingam and Kanehiro (1973) in a field study.

Further, it was interesting to note that the concentration of NO_3-N in soil during the active period of crop growth with the application of 40 and 80 kg N/ha along with FYM was either statistically at par or higher than the concentrations obtained with their respective high levels without FYM (Tables 4.1a and 4.2a). Therefore, a net saving of 40 kg N/ha could be effected with the application of FYM @ 10 tons/ha to ensure the nitrogen supply in soil equivalent to that obtained with the application of nitrogen fertilizer alone.

The application of Lantana camara resulted in the repression of both NO_3-N and NH_4-N throughout the experimental period. The reductions in NO_3-N were significant in most of the cases. The Lantana camara contains toxic substances like lantadene-A, tri-terpenoid, lantadene-B, lancamarone, quinine like alkaloid i.e. lantanine, and phenolic compounds (Joshi and Magar, 1952; Barton et al., 1954; Nigam et al., 1957; Sharma et al., 1980 ; Wadwani and Bhardwaj, 1981; Liebl and Worsham, 1983; Sharma, 1984; Rice, 1984; Acchireddy and Singh, 1984; Achhireddy et al., 1985 and Sinha and Saxena, 1987), which might have inhibited the microbial activity and applied-N transformations to NH_4-N and NO_3-N. Besides the enzymatic inhibitory role, the undecomposed plant parts of Lantana camara would result into considerable immobilization of soil available nitrogen as a result of wider C:N ratio. The immobilization of substantial amounts of added nitrogen as a result of application of straw in soil has been reported by Bhardwaj and Novak (1978). Similarly, the application of residues reduced both NH_4-N and NO_3-N concentrations in the surface soil depth in the straw treated plots than those in untreated plots at different levels of nitrogen application upto 160 kg N/ha (Rajput et al., 1984).

5.1.1.3 NO_3-N and NH_4-N as affected by irrigation.

During the entire growth period the concentrations of

NO_3-N and NH_4-N, in general, were higher under rainfed treatment compared to irrigated one and the differences were pronounced during the later part of the growth period (Tables 4.1 to 4.4). It appears that there was a dilution and displacement of soil available nitrogen to the deeper soil layers with the irrigation water.

5.1.2 Physical characteristics of Soil.

5.1.2.1 Soil moisture:

The soil water content determined in the surface 0-20 cm of soil, increased both with incorporation of organic matter and irrigation (Tables 4.5 and 4.6). The effect was more with the application of lantana. The organic materials when added to the soil are supposed to increase the water holding capacity of the soil. The effect of nitrogen application on soil water content was not significant during both the years i.e. 1984 and 1985.

5.1.2.2 Infiltration:

The infiltration rate as well as the cumulative infiltration, determined after the harvest of the crop during both the years of experimentation, were observed to be higher with the incorporation of FYM and lantana compared to no incorporation, the values being comparatively higher in the former than the latter (Tables 4.7 and 4.8). The addition of organic materials improves the structure of the soil which would offer more opportunity for water to enter into the soil. Accordingly, the soil water relations looked to be comparatively better with the incorporation of organic materials in the soil.

The high infiltration with soils having high organic matter levels has been reported by Khybri (1965) and Grin (1972). The increasing rates of nitrogen also increased the infiltration characteristics. The higher infiltration with higher rates of nitrogen application could be linked to the more loosening of the surface soil as a result of more tuberization/bulking as well as digging at harvest. The reduction in the infiltration due to irrigation is quite obvious as with flooding there would be lot of movement of clay particles into the transmission pores and channels carrying the infiltering water.

5.1.2.3 Bulk Density:

The bulk density of 0-15 cm soil layer, also determined after harvest of the crop during 1984 and 1985 was low with the incorporation of organic matter, especially FYM (Table 4.7 and 4.8). The organic residues in comparison to mineral fraction have low bulk density values and their incorporation is supposed to reduce the bulk density of soil. The bulk density values were also low with the inreasing levels of nitrogen. The low values of bulk density with higher levels of nitrogen application were also apparently due to the more loosening of soil under these treatments having more bulking of tubers.

5.2 Growth and development of potato as affected by different treatments.

5.2.1 Germination:

The germination count after 36 and 37 days of planting at regular interval of four days for almost a month revealed that there was a marked reduction in the emergence of potato with the application of Lantana camara (Table 4.9 and 4.10). The injurious effect of alkaloids in lantana was right from the germination of potato. The application of FYM, however, in general, encouraged the germination possibly through better soil, air and water relationships.

5.2.2 Height, number of branches and leaflets per plant.

5.2.2.1 Effect of N:

The increasing levels of nitrogen, generally, increased the height of plants, number of branches and number of leaflets per plant. There was quite conspicuous effect of nitrogen application on the height of the plant, as the increasing rates of nitrogen increased the height significantly all through the observed growth periods (Tables 4.13 and 4.14). The number of leaflets also significantly increased with the application of 120 kg N/ha compared to 80 kg, all through the growth period (Tables 4.21 and 4.22). However, the increase was not significant for the 80 kg N over 40 kg N. The effect of nitrogen application on the development of branches was significant only upto 80 kg N/ha beyond which the increase was not significant except on one date (Tables 4.17 and 4.18).It appeared that the increasing levels of nitrogen well maintained the nitrogen requirement by potato during the active phase of crop growth compared to low level. Singh (1975) reported an increase in plant height recorded at 45, 60, 75 and 90 days after planting with the application of 200 kg N/ha compared to 50 and 100 kg N/ha in the soils of Tarai region. The dry matter production also in their study was significantly influenced by nitrogen levels. It was significantly lower under control and

50 kg nitrogen level at all stages of plant growth as compared to 100 and 200 kg /ha levels. The maximum dry matter production at 75 days after planting was with the highest level of 200 kg N/ha. Khurana et al.(1977) reported the height of plants to be maximum with the application of 120 kg N/ha when the soils were adequately supplied with P and K. The shortest plants were noted in unfertilized controlled plots. The number of stems per hill was also significantly higher over control with the application of 60 kg N/ha with 50 kg each of P_2O_5 and K_2O. The results of Gupta (1969) were also similar who found an increase in the growth of potato with higher levels of nitrogen in combination with optimum levels of P and K. Hooda and Pandita (1980), similarly, reported an increase in the height of main shoot, number of stems per hill and number of tubers per hill with the application of 120 kg of Urea- N/ha compared to the lower levels during two years of study on the soils of Hissar.

5.2.2.2 Effect of organic matter:

The application of FYM @ 10 tons/ha, generally, significantly increased the height of plants, number of branches per plant and number of leaflets per plant compared to no incorporation. Therefore, it appeared that the incorporation of FYN better effected the growth and development of potato during the active phase of crop growth, possibly, through its positive effect on the moisture and nutrient supply. The application of FYM at 500 and 1000 quintal/ha has been reported by Singh (1975) to enhance plant growth. There was an increase in the production of dry matter due to the application of 250, 500 and 1000 quintals/ ha of FYM upto

75 days of planting, the greatest increase being observed upto 45 days of planting. The highest level of FYM i.e. 1000 q/ha caused the greatest dry matter production.

The application of lantana @ 10 tons/ha, however, unlike FYM, brought about a reduction in the growth and development of plant, the reduction being significant on some of the parameters on certain dates. The injurious effect of the alkaloids liberated in soil during the course of its decomposition might have affected the general growth and development of plant.

5.2.2.3 Effect of irrigation:

The irrigation significantly influenced the growth and development of potato in terms of plant height, number of branches per plant, number of leaflets per plant and tuber size compared to rainfed conditions. The better growth and development of potato under irrigated conditions is quite obvious in as much as the crop produces large foliage and stomata of potato plants are almost continuously open (Loftfield, 1921). Moreover, the potato plant has sparse and shallow root system and there is very little contribution in water supply from the deeper layers. Therefore, frequent irrigations, replenishing the water status in the surface depths, ought to increase the growth and development of plants compared to rainfed conditions.

5.2.3 Tuber size.

5.2.3.1 Effect of nitrogen:

The increase in levels of nitrogen did not have any significant effect on the proportion of small and medium grade potato tubers but the proportion of large size tubers was significantly higher with the application of 80 kg nitrogen over 40 kg level (Table 4.24). Reddy and Rao(1968) observed that application of nitrogen increased the weight of large sized tubers. Also Grewal et al.(1979) reported that nitrogen application increased the amount of large sized tubers significantly but had little effect on small size tubers. The yield of large size of tubers in their study increased with the increase in the levels of nitrogen and a significant increase was observed at 80 kg N/ha. Singh (1952), Hukkeri (1968), Herlihy and Carroll (1969) and Gupta and Saxena (1976,a) also reported that nitrogen application increased the size of tubers. This could be due to better early vegetative growth and longer period for tuber development. Moreover, the higher levels of nitrogen would have increased the weights of individual tubers as nitrogen is an integral constituent of Chlorophyll, necessary for the synthesization of food. It is also constituent of amino-acids and proteins and takes part in cell division and expansion.

5.2.3.2 Effect of organic matter:

The incorporation of FYM significantly increased and decreased the proportions of large and small grade potatoes, respectively, compared to no incorporation (Table 4.24). The FYM enhanced water and nutrient supply in the soils during the growth and development of potato which resulted also in increasing the size of tubers. It also made soil more pulverized, a necessary condition for the enlargement and bulking of tubers. Grewal and Trehan (1984) concluded from a two years field study on acidic brown hill soils of Shimla that significant increase in the production of large size tubers ($>$ 75 gm) was obtained with 30 t FYM/ha. Sharma (1986) also from two years study at Shimla reported that at 120 and 180 kg N/ha, the yield of large grade tubers was significantly high with FYM (30 t/ha). Similar effect of FYM application on the increase in the large grade of potato has been reported by Sahota et al.(1984). The poor growth and development of potato with the application of lantana also decreased the proportion of large size tubers, and increased that of smaller grade.

5.2.3.3 Effect of irrigation:

Irrigation influenced the grades of potato by significantly decreasing the proportion of small grade potato and increasing significantly that of large grade (Table 4.24). The continued moisture supply at low tensions is quite essential for the normal growth and development of potato plant. The better growth as a result of proper moisture and nutrient supply would ensure increased tuberization and bulking of potatoes.

5.3 Tuber yield as affected by different treatments:

5.3.1 Effect of N.

There was a large effect of the nitrogen application on the yield of potato (Table 4.26). The tuber yield increased significantly with the increasing levels of nitrogen upto 120 kg N/ha during 1985. During 1984 also there was an increase in yield due to increasing levels of nitrogen but the significant effect was noticed only upto 80 kg N/ha. The haulm yield also increased significantly with the increasing levels of nitrogen (Table 4.28). The effect is quite obvious as the nitrogen removal by the potato crop is quite high(Sharma et al. 1978; Singh and Grewal, 1979). A good crop of potato has been reported to remove about 120 kg N/ha in the acidic brown hill soils (Sharma et al. 1978). The peak period of nitrogen uptake is 60-80 days in the hills (Grewal and Sharma,1980) and in this study also the available nitrogen in the form of NO_3-N and NH_4-N was higher during this period with the application of higher levels of nitrogen. The concentration of NO_3-N during this period was significantly higher with higher levels of nitrogen and, therefore, the nitrogen supply was more favourable in as much as the potato preferred the uptake of nitrogen in the form of NO_3-N compared to other forms (Roberts and Cheng, 1984). Nitrogen is necessary to the plant from the time of germination to maturity for increased growth in terms of bearing more stems per hill, number of leaflets, height, number of branches, tuber number and tuber size. In this study also the increased levels of nitrogen increased the emergence of sprouts, height, number of branches per hill and number of leaflets per hill. The tuber size was also influenced by the levels of nitrogen application as the proportion of large grade tubers was significantly higher with the application of 80 kg N/ha compared to 40 kg N/ha. A substantial increase in the yield of potato tubers with increase in nitrogen application is mainly due to increase in the weight of individual tubers (Hanley et al., 1965). This effect of increased plant growth during the active phase of growth and increased tuber size was evident as well on the final yield of potato tuber. Significant potato responses to nitrogen application have been reported in different agro-climatic conditions of India and abroad and the response and optimum dose have been found to differ with the soils (Ramanujam and Singh, 1956; Sawyer and Dallyn, 1958; Black and Cairns, 1958; Kanwar, 1962; Pushkarnath and Sardana, 1964; Benepal, 1967; Reddy and Rao, 1968; Singh *et al.*, 1968; Hukkeri, 1968; Yadav and Tripathi, 1972; Khurana *et al.*, 1977; Grewal and Sharma, 1978; Grewal *et al.*, 1979; Grewal and Sharma, 1980; Hooda and Pandita, 1980; Grewal and Sharma, 1981; Singh and Grewal, 1983 and Sahota and Govindakrishnan, 1984). However, in the hill soils of Himachal Pradesh, Assam, Meghalaya and Jammu and Kashmir, where the organic matter and nitrogen content is high, the response was upto 92 kg/ha (Grewal and Sharma, 1980). The more recent study for three years, conducted on the acid hill soils of Shimla by Sharma (1986) revealed a highly significant potato response to nitrogen in the presence of 80 kg P_2O_5 + 160 kg K_2O/ ha and in the presence of FYM@ 30 t/ha. The dose of nitrogen for maximum tuber yield (39.9 t/ha) with P and K was 194 kg/ha, whereas, for maximum yield with FYM (33.2 t/ha) it was 128 kg/ ha.

5.3.2 Effect of organic matter:

The yield of potato increased significantly with the application of FYM @ 10 tons/ha compared to no incorporation during both the years of experimentation (Table 4.26). The per cent increases in yield with the application of FYM over no incorporation were 36.0 and 73.0 during 1984 and 1985, respectively. The application of FYM would enhance N use efficiency by crop by effecting slow release of applied, native as well as the N-contained in the FYM itself into the soils. The various organic compounds in FYM would complex nitrogen and make it slowly available to plants during the course of their decomposition. The application of nitrogen in the absence of organic fertilizers would result into considerable loss of nitrogen from the active root zone with the percolating water as well as due to volatilization. There is evidence to show that the incorporation of FYM increased the efficiency of fertilizer by 20-35 per cent and increased response of potatoes to nitrogen (Ionas et al. 1980). Besides enhancing the nitrogen supply from the fertilizer and native sources, the nitrogen contained in FYM itself(approximately 50 kg/10 tons of FYM) would be an additional source of nitrogen in the crop. The P and K supply would also be augmented comparatively with the application of FYM (20 and 50 kg of P_2O_5 and K_2O per 10 tons of FYM, respectively). The application of FYM @ 30 t/ha has been reported to adequately supply the P and K needs of potato in the absence of application of P and K fertilizers under the acid hill soils of Shimla (Sharma et al., 1980). The FYM is also a source of many micro-nutrients and other biotic substances which have direct bearing on the growth performance of the potato. These micronutrients are reported to become limiting in the potato growth,especially,at higher levels of nitrogen application, but the FYM would provide these nutrients in the required amount (Black and White,1973).The FYM is also known to be as an amendment for improving upon the various physical processes directly related to the yield of potato.Its addition would make the soils more pulverized and aerated, the ideal conditions for more tuberization(Sommerfeldt and Knutson, 1968,a; Bhatia and Shukla, 1982). There would also be an improvement in the water retention and transmission characteristics of the soil with the addition of FYM (Gattani et al., 1976). In our study also we noticed a decrease in the bulk density, increase in the moisture content and infiltration characteristics of the soils. The higher soil nitrogen supply and the improvement in physical characteristics with the application of FYM positively influenced the growth of potato during the active phase of crop growth and this effect persisted through the harvest by increasing tuber size and yield.

The incorporation of lantana resulted in reduction in tuber yield compared to no incorporation and the reduction was significant during one of the years. Also there was a decrease in the haulm yield with application of lantana compared to no incorporation (Table 4.28). It appeared that the deleterious effect of application of lantana continued upto harvest starting right from sprouting and active growth phase. The *Lantana camara* contains toxic substances like lantadene-A, tri-terpinoid, lantadene-B, lancamarone and quinine like alkaloids i.e. lantanine (Joshi and Magar, 1952; Barton *et al.*, 1954; Wadwani and Bhardwaj, 1981; Sharma, 1984; Rice, 1984; Acchireddy *et al.*, 1985 and Sinha and Saxena, 1987), the release of which during the course of its decomposition will have inhibited/delayed the sprouting, growth and development of potato. It also adversely affected the nitrogen supply in soils by inhibiting the microbial activity. The contents of NO_3-N were significantly lower with the application of lantana.

5.3.3 Effect of irrigation:

Irrigation significantly increased the tuber yield compared to rainfed conditions (Table 4.26). The yield in the former was almost double than the latter. The haulm yield was also significantly higher under irrigated than the rainfed conditions. The effect of irrigation was quite noteworthy right from the germination and early crop growth. The frequent irrigations for the maintenance of optimum moisture regime are quite important for ensuring high yields of potato (Taylor, 1952; Jones and Johnson, 1958; Myhre, 1958; Bhattacharjee, 1960; Prince and Blood, 1962; Yadav and Tripathi, 1972; Bhattacharjee et al., 1979 and Singh and Grewal, 1983). Various reasons have been advanced in support of the need of potato for moisture availability at very low moisture tensions. First, the potato is a short duration crop which produces large foliage and bulks up rapidly; ready availability of moisture is, therefore, essential for maintaining the leaves in turgid conditions and for tuber enlargement. Secondly, the stomata of the potato are almost continuously open (Loftfield, 1921), resulting in more transpiration. Thirdly, the potato plant has sparse and shallow root system in as much as nearly 70% of the water is depleted from the approximate 30 cm soil layer (Singh et al., 1968). Deeper layers did not contribute materially to the water supply of the crop.

5.3.4 Tuber yield as affected by interactions between N levels, irrigation and organic matter incorporation:

The interaction between irrigation and nitrogen levels indicated that during 1985, the yield of potato increased significantly with increasing levels of nitrogen both under rainfed and irrigated conditions. During 1984, the significant increase was not consistent. However, the yields during both the years under irrigated conditions were almost double at all the levels of nitrogen application compared to rainfed situations (Table 4.25 a). An increasing response of potato to nitrogen application with the more favourable water regime has been reported by Singh et al.(1968). A strong positive interaction between irrigation and nitrogen was reported by Singh and Swaminathan (1957) in their experiments carried out at Patna. Also, a positive interaction between irrigation and nitrogen levels for potato production has been shown by Singh and Grewal (1983) on alluvial soils of Patna during three years of study. The optimum nitrogen levels increased with the increase in irrigation level.

The interaction between organic matter and irrigation levels showed that there was a significant effect of application of FYM on tuber yield both under rainfed and irrigated conditions (Table 4.25 b). The increase in tuber yield was almost double with irrigation compared to rainfed conditions when FYM was applied in both the cases. It appears that under rainfed conditions the water needs of the crop were not fully met with and irrigation was quite essential for realising the optimum yields of crops. The interaction between organic matter and irrigation further revealed that the application of lantana brought about a significant reduction in yields under irrigated conditions compared to the no incorporation, but under rainfed conditions there was significant reduction during one year and yield was at par during the year 1984. The comparatively more reduction in tuber yield under irrigated conditions might be due to more decomposition and liberation of toxic substances conditioned by better moisture regimes.

The interactions between nitrogen levels and organic matter incorporation for the year 1985 (Table 4.25 c) as well as for pooled data revealed that the yields obtained with the application of 40 kg N/ha along with FYM @ 10 t/ha were significantly higher than the yields obtained with the highest N dose without FYM. As such with the application of FYM @ 10 t/ha there could be a considerable saving of inorganic nitrogen. Addition of nitrogen in combination with FYM has been reported to increase the response of potato to nitrogen by different workers (Dimitrov, 1964; Below, 1968; Shloma, 1968; Singh, 1975; Singh and Sharma, 1983; Sahota and Govindakrishnan., 1984 and Sharma, 1984). The increased efficiency of nitrogen (20-25%) and increased yield of potato by the application of FYM has also been reported by Vanha(1978), Ram et al.(1979), Grewal and Sharma (1981) and Sahota and Grewal (1984). The treatment receiving FYM remained superior even at high rates of nitrogen (Singh and Sharma, 1983).Sharma et al.(1980) reported that CAN plus FYM gave 2.67 times higher tuber yield than CAN alone. This was due to higher percentage of photosynthates translocated from tops to tuber and improvement in N utilization by potato. Sharma (1986) observed that the response of potato to nitrogen application continued to increase upto 250 kg N/ha in the presence of FYM.

The interaction (MxN) indicated significantly lower yield with the application of lantana compared to the yields at corresponding levels of nitrogen without incorporation of organic manure. The tuber yield with the application of 120 kg nitrogen plus lantana was at par with the yield with application of 40 kg nitrogen alone. From the above observations it becomes aptly clear that there are absolutely no possibilities of lantana as such being recommended as a source of organic matter to potato crop. However, its value as organic manure could be raised after well decomposing it before adding to the soil. The application of lantana in the raw form at planting would do more harm than good in terms of improving the microbial-chemical environment of soil.

As revealed by the interaction between nitrogen levels, organic matter incorporation and irrigation during 1985, the maximum response of potato was obtained with the application of 120 kg N/ha along with FYM @ 10 t/ha under irrigated conditions (Table 4.25 d). The yield under this treatment (253.31 q/ha) was significantly higher than rest of the treatments.

It is difficult to say as to how much could be the substitution of inorganic nitrogen by the application of FYM, separately under irrigated and rainfed conditions as the interaction between nitrogen levels, irrigations and organic matter incorporation was not significant during 1984 as well as for pooled data. However, on the basis of significant interaction for one year, it was observed that the yields under rainfed conditions with the application of 80 kg N/ha along with

FYM were significantly higher than with the application of 120 kg N alone. This apparently showed that with the application of FYM under rainfed conditions there was substitution of inorganic nitrogen equivalent to 40 kg/ha. The substitution under irrigated conditions looked to be the even higher. Seeing the effect of FYM application on N-substitution from the NxM interaction as well as from NxMxI interaction for one year, we can say that at least 40 kg N/ha could be substituted with the application of FYM @ 10 t/ha to potato both under rainfed and irrigated conditions. The farmers could this way very well economise on their nitrogen needs at the farm.

For finding out the response and optimum dose of nitrogen for potato under irrigated conditions along with application of FYM, the data on yield were fitted on to quadratic type of equation. There was linear response of potato to the application of nitrogen of the type $Y = a-bx+cx^2$ upto 120 kg N/ha which signified that with the application of increasing levels of nitrogen, the yield of potato increased linearly. As such, potato would respond to still higher rates of nitrogen than tried in the present investigation.

5.4 Starch, reducing and non-reducing sugars as affected by different treatments.

5.4.1 Starch content:

The increasing rates of nitrogen and irrigation and application of FYM brought about reduction in the starch content of tubers (Table 4.30). The reduction with the increasing rates of nitrogen was significant during one year. In the other year also the significant reduction was observed with the application of 120 kg nitrogen. The effect of irrigation on reduction of starch compared to rainfed conditions was significant during both the years. The significant effect of application of FYM on the reduction compared to no incorporation was evident only during one year. The increase in the levels of nitrogen increases protein content and brings a concomitant decrease in starch content of potato (Sinha et al., 1967). The inverse relationship between protein and starch content with increasing levels of N are well explained on the basis of the function of N in protein synthesis and carbohydrate utilization (Yadav and Tripathi, 1972). Similarly, the increased moisture availability and application of FYM effecting an increase in the nitrogen availability are anticipated to bring about a decrease in the starch content of tubers. Supersperg (1967) reported reductions in the starch content of potato tubers with increased moisture supply which may be attributed to higher use of carbohydrate for increased crop growth, resulting in higher yields. The increased levels of nitrogen have been reported to decrease starch content of potato (Prince et al., 1940; Smith, 1940; Terman, 1950; Black and Cairns, 1958; Reddy and Rao, 1968; Hukkeri, 1968; Majur & Gawlick, 1977 and Barsukov, 1982). Barsukov (1982) also reported that higher soil moisture and application of FYM had adverse effect on the starch content of tubers, respectively.

5.4.2 Reducing and non-reducing sugars:

There was a reduction in the content of both in reducing and non-reducing sugars with the increasing levels of nitrogen but the increase was not significant in most of the cases (Table 4.30). Irrigation also decreased the reducing and non-reducing sugars compared to rainfed treatment and the reduction was significant for non-reducing sugars during both the years. The incorporation of organic matter in the form of both FYM and lantana also caused reduction in the contents of both reducing and non-reducing sugars, the reduction being more with FYM than with lantana. The reduction in non-reducing sugars was significant with the application of FYM during both the years, whereas, with lantana it was during one year. It has been reported by Mazur and Gawlick (1977) that the application of nitrogen affected the reducing sugar significantly and reduced the content in tubers from 1.4 per cent at 120 kg N/ha to 1.22 per cent at 240 N/ha. The increasing levels of nitrogen have been reported to decrease the total sugar contents of Kinnow (Sharma, 1982). The FYM might have indirectly influenced the reduction in the total sugar content of potato through its effect on the enhanced nitrogen availability and moisture supply.

SUMMARY & CONCLUSION

SUMMARY

The field experiments were conducted during 1984 and 1985 on the experimental farm of Himachal Pradesh Krishi Visnva Vidyalaya to study the, " Response of potato to nitrogen as influenced by irrigation and organic matter". The texture of the soil was clay loam and the soils are classified as typic hapludalf. The soils are acidic in nature, the pH being 5.7. The results of the experiments are summarized below:

1) The soil concentrations of NO_3-N and NH_4-N increased with the application of increasing levels of nitrogen, the increase in NO_3-N being significant. The concentration of NO_3-N and NH_4-N increased with time after application at sowing; the maximum generally being after 40-60 days of application. The concentrations also increased after second dressing for some time and declined thereafter.

2) The application of irrigation, generally, decreased the soil concentrations of both NO_3-N and NH_4-N.

3) The incorporation of FYM @ 10 t/ha before sowing resulted in higher concentrations of both NO_3-N and NH_4-N in soil throughout the growth period compared to no incorporation. The increase was especially more pronounced, with significant effect, for NO_3-N with the advancement of crop growth.

4) Unlike the effect of FYM, the incorporation of Lantana camara resulted in the repression of both NO_3-N and NH_4-N in soil throughout the crop growth.

5) The incorporation of organic matter in the form of FYM as well as *Lantana camara* increased the soil moisture content, decreased bulk density and increased the rate of infiltration in soils. The improvement in physical characteristics was comparatively more with FYM.

6) The increasing levels of nitrogen, generally, increased the height of plants, number of branches and number of leaflets per plant. The effect of nitrogen application was quite conspicuous on the height of the plant as the increasing rates of nitrogen increased the height significantly all through the observed growth period.

7) The incorporation of FYM @ 10 t/ha, generally, increased the height of the plants, number of branches per plant and number of leaflets per plant significantly compared to no incorporation.

8) The application of lantana @ 10 t/ha, however, unlike the effect of FYM brought about reduction in emergence, growth and development of plant. Also, its application delayed the emergence of potatoes.

9) Irrigation significantly increased the growth and development of plant in terms of plant height, number of branches and number of leaflets per plant compared to rainfed conditions.

10) There was a large effect of nitrogen application on the yield of potato. The yield increased significantly with the increase of nitrogen upto 120 kg N/ha during one year. During second year also there was an increase in yield due to increasing levels of nitrogen but the significant effect was upto 80 kg N/ha.

11) The yield of potato increased significantly with the application of FYM @ 10 t/ha compared to no incorporation. The yield increase was significant both under rainfed and irrigated conditions with its application. Application of FYM @ 10 t/ha could substitute at least 40 kg inorganic N/ha to potato crop.

12) Unlike the effect of FYM, the incorporation of lantana, irrespective of irrigation, resulted in significant reduction in tuber yield compared to no incorporation. The reduction in yield with its application was significant under irrigated conditions, whereas, it was not significant under rainfed conditions. As such, there was no possibility of its substituting FYM as a source of organic matter for potato.

13) Irrigation significantly increased the tuber yield compared to rainfed conditions. The yield in the former was almost double than the latter.

14) The maximum tuber yield was obtained with the application of 120 kg N/ha along with FYM @ 10 t/ha under irrigated conditions. The response to nitrogen with the application of FYM and irrigation was linear upto 120 kg N which suggested that potato would respond to still higher levels of nitrogen.

15) The tuber size distribution was also influenced by nitrogen application, irrigation and organic matter incorporation. The application of nitrogen @ 80 kg/ha significantly increased the proportion of large grade potato ($>$ 50 gm)compared to the level of 40 kg N/ha. The increasing

levels of nitrogen did not influence significantly the proportion of small (< 25 gm) and medium (25-50 gm) grade potatoes.

16) The irrigation significantly increased the proportion of large grade potato but decreased the proportion of small grade potato.

17) The incorporation of FYM also significantly increased the proportion of large grade potatoes and decreased significantly that of small grade. However, reverse was the case with the application of lantana.

18) The increasing rates of nitrogen, irrigation and FYM incorporation, generally, brought reduction in the contents of starch, reducing and non-reducing sugars.

Conclusion:

From the foregoing discussion, it could be concluded that for realising higher tuber yields and better quality of the produce in the Palam Valley of Himachal Pradesh, the potato crop should be raised under irrigated conditions with application of 120 kg N/ha along with FYM @ 10 t/ha. The obnoxious weed, *Lantana camara*, as such in raw form, by no means could substitute FYM as a source of organic matter to potato as its deleterious effect on growth and development of potato was observed right from the germination stage. The harmful effect of *Lantana camara* appears to be due to very high dose as it was applied on air dry basis. There is need to try lower levels of application on fresh weight basis after partial decomposition of the material in the soil.

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LITERATURE CITED

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APPENDICES

Appendix-I NO_3-N (kg/ha) in soil as affected by different treatments (1984)

Treatments			1.3.84	21.3.84	10.4.84	30.4.84	20.5.84	4.6.84
N_1	M_o	I_o	31.25	76.05	81.45	30.99	93.05	48.00
		I_1	31.22	76.82	73.42	24.92	85.00	35.77
	M_1	I_o	24.75	68.10	71.90	25.37	68.04	38.10
		I_1	27.80	67.75	62.82	18.87	51.05	25.62
	M_2	I_o	42.90	103.45	95.40	41.82	141.55	71.27
		I_1	41.75	100.45	89.00	21.40	141.05	51.95
N_2	M_o	I_o	33.30	84.40	87.45	35.60	117.38	46.10
		I_1	33.33	97.35	84.72	26.65	99.32	34.02
	M_1	I_o	27.45	81.75	76.67	33.27	103.85	46.10
		I_1	31.25	89.20	73.25	32.67	83.17	34.02
	M_2	I_o	46.95	110.75	119.47	50.80	164.15	73.87
		I_1	44.25	108.27	109.55	34.77	138.37	57.92
N_3	M_o	I_o	39.50	96.65	92.45	36.69	133.42	67.97
		I_1	35.97	92.15	88.60	39.85	113.62	43.80
	M_1	I_o	31.20	92.42	82.54	35.80	128.49	53.30
		I_1	33.07	90.25	85.60	34.82	97.05	39.45
	M_2	I_o	56.50	122.17	125.60	63.87	195.65	80.07
		I_1	54.10	199.47	119.10	48.00	147.12	64.12
SE m±			2.87	3.65	2.93	2.66	3.68	3.30
C.D. at 5%			8.26	10.52	8.45	7.66	10.59	9.50
C.V.			13.43	6.78	5.65	13.05	5.53	11.09

Appendix-II NO_3-N (kg/ha) in soil as affected by different treatments(1985)

Treatments			6.2.85	26.2.85	18.3.85	7.4.85	27.4.85	17.5.85
N_1	M_o	I_o	49.97	36.11	63.19	158.31	99.30	80.46
		I_1	31.51	40.08	49.56	111.60	70.65	61.84
	M_1	I_o	29.66	38.75	51.55	115.46	67.40	53.35
		I_1	32.54	43.81	41.48	102.60	49.75	47.95
	M_2	I_o	45.69	59.13	78.50	196.45	114.50	91.85
		I_1	52.28	49.33	60.59	121.71	95.40	77.15
N_2	M_o	I_o	39.62	44.21	71.75	154.79	115.40	107.88
		I_1	45.67	60.48	54.69	128.18	92.20	84.97
	M_1	I_o	45.81	40.08	59.02	109.70	89.14	59.93
		I_1	42.60	46.33	46.92	85.90	60.09	55.69
	M_2	I_o	55.58	58.87	84.92	209.65	133.06	124.41
		I_1	45.62	52.23	69.59	184.11	115.15	95.96
N_3	M_o	I_o	42.31	66.40	70.27	175.69	130.00	122.13
		I_1	49.89	56.62	72.23	143.00	114.25	79.70
	M_1	I_o	51.15	44.04	63.68	149.67	105.25	87.95
		I_1	40.46	45.90	57.27	141.91	81.10	72.05
	M_2	I_o	58.05	80.51	97.50	224.70	209.60	150.00
		I_1	68.55	67.92	85.38	166.41	180.09	114.08
SEm±			4.17	4.60	4.39	9.05	9.04	6.13
C.D. at 5%			12.00	13.23	12.63	26.05	26.02	17.64
C.V.			15.74	15.41	11.62	10.53	14.67	12.20

Appendix-III NO_3-N(kg/ha) in soil as influenced by IxN interaction (1984)

Treatment	10.2.84		20.5.84	
	I_o	I_1	I_o	I_1
N_1	28.47	27.28	100.88	83.36
N_2	30.01	25.31	128.46	106.95
N_3	23.41	30.30	152.52	119.26
	SEm± =	1.76	SEm± =	2.12
	C.D. at 5% =	5.02	C.D. at 5% =	6.11

Appendix-IV NO_3-N (kg/ha) in soil as influenced by IxM interaction (1984)

Treatment	30.4.84		20.5.84	
	I_o	I_1	I_o	I_1
M_o	31.48	28.79	115.17	99.31
M_1	52.16	34.72	101.02	77.09
M_2	34.43	30.47	167.11	133.18
	SEm± =	1.53	SEm± =	2.12
	C.D. at 5% =	4.42	C.D.at 5% =	6.11

Appendix-V NO_3-N (kg/ha) in soil as influenced by IxN interaction (1985)

Treatments	17.5.85	
	I_o	I_1
N_1	75.55	62.31
N_2	97.40	78.87
N_3	120.02	88.61
	SE m± = 3.54	
	C.D. at 5% = 10.18	

Appendix-VI NO_3-N (kg/ha) in soil as influenced by IxM interaction (1985)

Treatments	26.2.85		17.5.85	
	I_o	I_1	I_o	I_1
M_o	48.91	52.39	103.49	75.50
M_1	40.96	45.36	67.07	58.56
M_2	66.17	56.50	122.08	95.73
	SE m± =	2.65	SE m± =	3.54
	C.D. at 5% =	7.64	C.D. at 5% =	10.18

Appendix-VII NH$_4$-N (kg/ha) in soil as affected by different treatments (1984)

Treatments			1.3.84	21.3.84	10.4.84	30.4.84	20.5.84	4.6.84
N_1	M_o	I_o	18.80	14.47	23.57	10.80	27.05	27.07
		I_1	19.47	8.80	20.22	5.77	18.65	17.42
	M_1	I_o	15.60	9.70	14.80	13.90	20.35	21.95
		I_1	18.82	8.34	12.00	8.90	15.92	15.52
	M_2	I_o	20.95	12.60	26.20	11.90	43.70	24.15
		I_1	19.55	15.20	17.42	9.32	35.05	22.77
N_2	M_o	I_o	20.85	11.55	26.40	15.85	39.17	28.30
		I_1	21.74	10.70	22.15	12.35	33.02	19.45
	M_1	I_o	17.42	10.35	25.25	11.45	30.35	20.00
		I_1	18.77	15.22	18.77	10.70	20.80	17.50
	M_2	I_o	22.82	25.60	29.65	17.20	63.40	31.00
		I_1	21.72	20.97	26.25	12.35	44.62	25.25
N_3	M_o	I_o	21.00	17.50	29.55	17.20	58.45	36.30
		I_1	22.87	27.01	25.30	17.42	41.20	25.30
	M_1	I_o	19.47	16.70	30.22	16.50	51.65	28.92
		I_1	22.87	11.81	25.15	14.70	26.67	25.15
	M_2	I_o	25.60	29.85	45.90	23.50	76.40	45.12
		I_1	24.15	22.52	40.95	23.70	67.30	26.62
SE m$\pm$			1.82	1.71	2.46	1.37	2.09	2.26
C.D. at 5%			NS	4.94	7.08	3.95	6.03	6.50
C.V.			15.28	18.55	16.71	16.89	9.14	15.40

Appendix- VIII NH_4-N (kg/ha) in soil as affected by different treatments(1985)

Treatments			6.2.85	26.2.85	18.3.85	7.4.85	27.4.85	17.5.85
N_1	M_o	I_o	59.96	18.62	38.62	53.93	29.31	38.94
		I_1	52.70	16.62	36.33	55.41	32.85	36.51
	M_1	I_o	35.06	17.70	27.66	47.32	35.30	37.35
		I_1	55.26	20.00	21.75	42.48	27.84	30.78
	M_2	I_o	59.44	24.74	49.00	57.16	62.14	37.92
		I_1	68.82	33.12	41.83	54.44	40.34	32.87
N_2	M_o	I_o	64.14	25.37	42.66	50.46	49.73	44.83
		I_1	60.87	21.99	39.37	48.95	34.92	37.32
	M_1	I_o	75.21	33.84	37.41	55.39	40.18	32.70
		I_1	63.61	38.75	36.33	40.74	38.37	34.69
	M_2	I_o	61.78	28.37	58.30	82.34	47.79	46.97
		I_1	73.78	30.12	44.30	78.23	61.19	42.00
N_3	M_o	I_o	79.64	37.24	51.50	65.52	61.25	53.97
		I_1	77.56	46.37	39.34	59.20	49.77	35.02
	M_1	I_o	64.39	22.74	43.58	50.47	37.93	47.82
		I_1	60.87	22.87	37.16	63.70	38.46	36.76
	M_2	I_o	91.12	40.30	62.41	75.60	66.80	59.36
		I_1	87.38	36.45	55.35	59.05	53.40	44.57
SE m±			4.18	2.97	3.97	3.99	3.80	2.85
C.D. at 5%			12.08	8.54	11.40	11.48	10.95	8.21
C.V.			10.95	17.97	16.20	11.95	14.69	12.19

Appendix-IX NH_4-N (kg/ha) in soil as influenced by IxN interaction (1984)

Treatments	20.5.84	
	I_0	I_1
N_1	30.36	23.20
N_2	44.30	32.81
N_3	62.16	45.39
	SEm ± =	1.21
	C.D. at 5% =	3.48

Appendix-X NH_4-N (kg/ha) in soil as influenced by IxN interaction (1985)

Treatments	27.4.85		17.5.85	
	I_0	I_1	I_0	I_1
N_1	42.24	33.68	38.03	33.39
N_2	45.90	44.83	41.50	38.00
N_3	55.32	47.21	53.71	38.78
	SEm± =	2.19	SEm± =	1.64
	C.D. at 5% =	6.32	C.D. at 5% =	4.74

Appendix-XI NH_4-N (kg/ha) in soil as influenced by NxM interaction (1984)

Treatments	21.3.84			10.4.84			30.4.84			20.5.84		
	M_0	M_1	M_2	M_0	M_1	M_2	M_0	M_1	M_2	M_0	M_1	M_2
N_1	11.64	9.02	13.90	21.89	13.40	21.81	8.28	11.40	10.61	22.85	18.13	39.37
N_2	11.11	12.79	23.28	24.27	22.01	27.95	14.10	11.07	14.77	36.09	25.57	54.01
N_3	22.25	14.25	26.18	27.42	27.68	26.75	17.31	15.60	23.60	49.82	39.66	71.85
	SEm± = 1.21			SEm± = 1.74			SEm± = 0.97			SEm± = 1.48		
	C.D. at 5% = 3.49			C.D.at 5% = 5.01			C.D.at 5% = 2.79			C.D.at 5% = 4.26		

Appendix-XII NH_4-N (kg/ha) in soil as influenced by NxM interaction (1985)

Treatments	6.2.85			7.4.85			27.4.85		
	M_0	M_1	M_2	M_0	M_1	M_2	M_0	M_1	M_2
N_1	56.33	45.16	64.13	54.67	44.90	55.80	31.08	31.56	51.24
N_2	62.50	69.41	67.78	49.70	48.06	80.29	42.32	39.27	54.49
N_3	78.60	62.63	89.25	62.36	57.08	67.33	55.51	38.19	60.10
	SEm± = 2.91			SEm± = 2.82			SEm± = 2.69		
	C.D. at 5% = 8.51			C.D. at 5% = 8.12			C.D. at 5% = 7.74		

Appendix-XIII The soil moisture content expressed on per cent mass basis under IxN and NxM interaction (1984)

Treatment	16.3.84		6.4.84		
	I_o	I_1	M_o	M_1	M_2
N_1	16.69	19.03	22.80	23.42	21.38
N_2	20.81	18.98	22.61	21.91	24.24
N_3	19.37	20.45	21.99	23.00	22.20
	SEm ± =	0.58	SEm ± =		0.61
	C.D. at 5% =	1.68	C.D. at 5% =		1.78

Appendix-XIV The soil moisture content (%) on mass basis during crop growth under IxN interaction (1985)

Treatments	4.5.85	
	I_o	I_1
N_1	15.81	27.14
N_2	18.57	27.68
N_3	15.13	27.29
	SEm ± =	0.53
	C.D. at 5% =	1.53

Appendix- XV The soil moisture content(%) on mass basis during crop growth under IxM interaction (1985)

Treatment	6.4.85		4.5.85		25.5.85	
	I_o	I_1	I_o	I_1	I_o	I_1
M_1	17.86	23.43	18.46	27.30	11.88	18.11
M_2	21.91	22.96	16.56	27.89	12.08	16.95
M_3	19.47	24.75	14.48	26.92	13.08	16.93
	SE m±	= 0.81	SE m±	= 0.53	SE m±	= 0.57
	C.D. at 5%	= 2.33	C.D. at 5%	= 1.53	C.D. at 5%	= 1.64

Appendix- XVI The soil moisture content(%) mass basis during crop growth under NxM interaction (1985)

Treatment	4.5.85			11.5.85		
	M_o	M_1	M_2	M_o	M_1	M_2
N_1	22.29	21.70	20.43	17.58	17.36	18.39
N_2	25.75	23.07	20.54	17.58	18.50	17.59
N_3	20.59	21.90	21.13	16.57	19.72	16.15
	SE m±	=	0.65	SE m±	=	0.69
	C.D. at 5%	=	1.88	C.D. at 5%	=	2.00

Appendix- XVII Pooled yield(%) of small grade potatoes as influenced by IxN interaction (pooled yield of 1984 and 1985)

Treatments	I_0	I_1
N_1	24.15	18.21
N_2	19.54	19.87
N_3	23.57	19.39

SE m$\pm$ = 1.26

C.D. at 5% = 3.62

Appendix- XVIII Pooled yield (%) of large grade potatoes as influenced by NxM interaction(pooled yield of 1984 and 1985)

Treatments	M_0	M_1	M_2
N_1	38.56	26.60	43.07
N_2	40.50	40.24	48.86
N_3	43.19	24.87	4330

SE m$\pm$ = 2.65

C.D. at 5% = 7.64

Appendix- XIX Potato tuber yield of potatoes (q/ha) as influenced by NxM interaction (1984)

Treatments	M_o	M_1	M_2
N_1	65.25	58.91	89.16
N_2	92.94	80.83	24.19
N_3	98.88	89.98	136.28

SE m± = 7.47

C.D. at 5% = NS

Appendix- XX Potato tuber yield (q/ha) as influenced by NxIxM interaction (1984)

Treatments	I_o			I_1		
	M_1	M_2	M_3	M_1	M_2	M_3
N_1	38.24	52.63	37.19	79.58	125.69	93.32
N_2	53.88	73.58	45.60	107.77	174.80	140.27
N_3	57.44	76.11	52.38	122.50	196.46	145.38

SE m± = 10.57

C.D. at 5% = NS

Appendix- XXI Analysis of variance of NO_3-N (kg/ha) in soil at 20 days interval after planting during 1984

Sources of variations	d.f.	Mean sum of squares 20 DAP	40 DAP	50 DAP	80 DAP	100 DAP	120 DAP
Replication	2	104.41*	20.28	41.19	31.41	11.53	72.54
Treatment	17	245.38**	751.61**	950.22**	363.07**	3725.88**	683.60**
I	1	0.18	12.82	366.18**	870.41**	7835.63**	3214.30**
N	2	332.95**	1830.30**	1846.15**	1144.70**	8703.04**	724.47**
M	2	1654.33**	4246.32**	5643.90**	909.88**	17966.01**	3358.77**
I x N	2	5.21	92.76	32.91	47.41	301.36**	22.22
I x M	2	31.80	49.30	22.76	300.67**	394.33**	36.66
M x N	4	28.95	52.82	154.00**	104.64**	151.65*	7.26
I x M x N	4	1.72	28.98	20.04	19.47	42.08	23.43
Error	34	24.76	40.15	25.68	21.27	40.69	32.75

DAP = Days after planting.

Appendix- XXII Analysis of variance of NO_3-N (kg/ha) in soil at 20 days interval after planting during 1985

Sources of variation	d.f.	Mean sum of squares 20 DAP	40 DAP	60 DAP	80 DAP	100 DAP	120 DAP
Replication	2	35.10	239.15*	358.55**	242.88	157.42	303.47
Treatment	17	281.95**	431.21**	656.33**	4499.31**	4781.47**	2347.24**
I	1	11.23	4.86	1755.82**	15914.18**	7003.02**	5926.02**
N	2	591.15**	1133.29**	1299.35**	4930.19**	13542.63**	5703.65**
M	2	985.37**	1502.64**	3109.57**	19955.27**	19645.20**	9637.82**
I x N	2	39.18	166.08	118.00	432.80	3.27	405.00*
I x M	2	40.61	278.75*	46.48	1632.07	2.53	525.33*
M x N	4	103.31	236.20*	33.06	1284.16	1888.83**	322.33*
I x M x N	4	264.00**	54.87	30.68	384.23	84.84	36.06
Error	34	52.27	63.54	57.90	246.14	245.53	112.91

DAP = Days after planting.

Appendix- XXIII Analysis of variance of NH_4-N(kg/ha) in soil at 20 days interval after planting during 1984

Sources of variations	d.f.	Mean sum of squares 20 DAP	40 DAP	60 DAP	80 DAP	100 DAP	120 DAP
Replication	2	7.07	25.82	6.69	2.91	1.70	21.36
Treatment	17	18.37	130.16**	205.20**	66.99**	953.96**	154.10**
I	1	9.29	9.99	312.86**	88.78**	1882.69**	767.87**
N	2	65.08**	397.19**	866.66**	351.52**	3296.26**	475.28**
M	2	59.69**	387.61**	466.42**	69.32**	3511.47**	263.03**
1 x N	2	0.89	1.83	0.09	16.49	104.37**	42.93
1 x M	2	18.11	19.61	3.48	0.15	5.18	38.45
M x N	4	3.01	65.38**	117.11**	38.08**	49.74*	11.33
1 x M x N	4	0.85	82.20**	8.48	5.69	75.27*	41.77
Error	34	10.00	8.86	18.21	5.66	13.19**	15.35

DAP = Days after planting.

Appendix- XXIV Analyses of variance of NH_4-N (kg/ha) in soil at 20 days interval after planting during 1985

Sources of variations	d.f.	Mean sum of squares 20 DAP	40 DAP	60 DAP	80 DAP	100 DAP	120 DAP
Replication	2	21.91	38.79	22.53	29.05	71.42	79.57*
Treatment	17	524.45**	231.93**	309.71**	404.91**	438.47**	177.62**
I	1	17.03	50.20	587.53**	215.84*	472.65**	798.41**
N	2	2105.20**	723.57**	693.49**	525.53**	800.29**	508.59**
M	2	968.26**	184.32**	1454.89**	1490.55**	1661.83**	241.17**
IxN	2	140.08	3.70	13.90	27.29	679.70**	178.43**
IxM	2	115.54	1.69	28.99	48.60	30.77	22.78
MxN	4	366.36*	450.74**	40.27	429.37**	461.20**	57.91
IxMxN	4	193.76*	65.77	33.49	191.56**	2.02	21.92
Error	17	52.61	26.47	47.16	47.85	43.48	24.46

DAP = Days after planting.

Appendix XXV. Analyses of variance of moisture content (%) in soil (0-20 cm) at 7 days interval after planting during 1984

ource of variations	d.f.	Mean sum of squares														
		February		March					April				May			
		17th	24th	2nd	9th	16th	23rd	30th	6th	14th	21st	28th	5th	12th	19th	26th
eplication	2	2.18	1.66	2.12	9.06	1.06	0.06	2.18	1.87	15.37**	16.64**	5.97	5.16	3.72	3.66	5.82*
reatment	17	6.11	4.33	8.82*	9.20*	28.06**	22.31**	12.84**	8.18**	13.72**	17.18**	28.86**	29.72**	30.72**	2.47	5.93**
	1	0.01	0.94	0.38	1.88	3.79	3.15	3.27	98.36**	164.50**	211.34**	418.83**	450.14**	467.46**	20.31**	72.12**
	2	0.91	0.34	3.02	0.46	25.01**	11.70*	2.94	1.33	3.70	4.37	4.42	1.02	2.98	0.08	0.24
	2	34.26**	28.10**	46.93**	48.79**	168.85**	156.39**	86.83**	0.42	18.50**	17.75**	22.60**	10.10*	13.14**	7.21*	11.16**
xN	2	2.56	0.59	4.83	3.04	20.60**	7.10	8.90	0.21	1.79	6.85	0.30	5.50	1.41	0.05	0.08
xM	2	0.08	0.84	0.32	1.92	3.47	2.09	0.82	0.49	0.37	0.67	6.43	6.81	2.06	1.79	1.21
xN	4	6.60	1.61	5.32	5.90	4.43	3.17	1.53	8.21*	4.73	3.83	0.15	1.84	1.19	0.61	0.70
xMxN	4	3.79	1.63	4.50	5.65	4.92	2.23	3.61	0.76	0.27	1.86	0.95	0.23	2.73	0.25	0.15
rror	34	4.71	3.70	3.79	4.73	3.08	2.40	3.44	2.30	2.81	2.42	2.72	2.31	1.80	1.49	1.39

Appendix XXVI. Analyses of variance of moisture content (%) in soil (0-20 cm) at 7 days interval after planting during 1985

Sources of variations	d.f.	Mean sum of squares																
		Feb.				March					April				May			
		2nd	9th	16th	23rd	2nd	9th	16th	23th	30th	6th	13th	20th	27th	4th	11th	18th	25th
Rep.	2	21.83**	9.11*	11.11*	1.24	11.14**	10.56	4.79	25.55*	2.30	39.44**	10.52**	7.27	20.82**	3.63	4.92	1.31	8.75*
Treatment	17	3.19	0.98	2.34	3.55*	2.71	13.04*	5.36**	9.70*	20.33	21.62**	3.31*	5.82*	11.06**	109.18**	40.23**	18.30**	22.69**
I	1	4.21	0.46	12.58*	1.30	0.33	131.72**	28.03**	7.17	45.30	212.81**	21.15**	0.46	24.68*	1594.35**	593.02**	261.71**	334.90**
N	2	2.24	0.27	2.91	0.30	0.60	26.84*	10.65*	62.78**	82.49**	16.35	6.58*	0.26	4.44	19.37**	0.80	8.38**	1.05
M	2	4.25	1.11	0.06	3.24	17.94**	3.19	1.12	0.63	11.64	0.73	0.53	34.98**	47.85**	27.50**	8.96	3.79	1.39
IxN	2	5.89	0.92	2.17	2.14	0.10	3.33	5.48	0.64	16.53	28.79*	4.25	0.02	3.47	11.18*	1.11	0.69	2.64
IxM	2	6.02	2.27	0.88	0.22	0.49	3.09	1.98	2.34	10.25	10.03	0.25	0.02	6.91	10.29*	2.83	0.83	6.43*
MxN	4	5.00	0.88	0.40	1.31	1.07	3.14	2.88	3.30	7.46	7.82	0.91	3.59	7.24	18.00**	17.41**	0.40	2.01
IxMxN	4	0.54	0.87	3.57	10.54	0.80	1.15	3.29	3.17	7.91	2.93	2.05	1.50	2.28	13.26**	7.17	5.12*	4.95
Error	34	2.19	2.57	2.41	1.85	2.01	6.06	2.08	5.04	11.53	5.91	1.42	2.41	3.85	2.57	2.90	1.53	1.95

Appendix- XXVII Analysis of variance of germination (percentage) of potato at different dates during 1984

Sources of variations	d.f.	Mean sum of squares							
		17.3.84	21.3.84	25.3.84	29.3.84	2.4.84	6.4.84	10.4.84	14.4.84
Replication	2	0.059*	14.719**	4.888*	3.851*	0.152	3.37**	1.182**	0.624*
Treatment	17	0.120**	10.364**	9.447**	4.203**	2.565**	1.22**	0.630**	0.308
I	1	0.003	0.039	0.435	0.715	0.010	0.711	0.3935	0.0740
N	2	0.009	0.234	0.760	0.779	0.954	0.587	0.576	0.102
M	2	0.825*	77.285**	77.664**	33.270**	19.021**	8.863**	4.109**	2.218**
IxN	2	0.0327	3.167	0.068	0.478	0.481	0.028	0.010	0.009
IxM	2	0.059**	2.796	0.346	0.165	0.101	0.173	0.103	0.022
MxN	4	0.0167	1.775	0.218	0.082	0.290	0.186	0.171	0.030
IxMxN	4	0.0326	0.636	0.402	0.389	0.329	0.018	0.011	0.092
Error	34	0.013	1.232	0.924	0.890	0.747	0.230	0.207	0.154

DAP = Days after planting.

Appendix- XXVIII Analysis of variance of germination percentage of potato at different dates during 1985

Sources of variation	d.f.	Mean sum of squares								
		1.3.85	5.3.85	9.3.85	13.3.85	17.3.85	21.3.85	25.3.85	29.3.85	5.4.85
Replication	2	5.218**	0.484	0.520	0.270	0.002	0.031	0.485	0.011	0.014
Treatment	17	2.930**	9.754**	9.153**	5.988**	6.744**	2.379**	1.449**	0.580**	0.075**
I	1	0.371	2.033*	0.302	0.673	0.550	1.309**	0.564	0.938**	0.072*
N	2	0.180	0.656	0.319	1.618*	1.281**	0.040	0.130	0.158	0.041*
M	2	21.54**	79.237**	75.863**	47.318**	55.58**	17.380**	5.380**	2.613**	0.492**
1xN	2	0.239	0.076	0.235	0.141	0.021	0.001	0.392	0.186*	0.001
1xM	2	0.149	0.386	0.434	0.129	0.006	2.177**	2.727**	1.125**	0.047*
MxN	4	0.353	0.499	0.145	0.413	0.044	0.068	0.146	0.066	0.009
1xMxN	4	0.950	0.269	0.257	2.755**	0.034	0.035	0.262	0.125*	0.004
Error	34	0.379	0.443	0.261	0.384	0.089	0.106	0.352	0.043	0.010

Appendix- XXIX Analysis of variance of average height(cm) of potato on different dates during 1984

Sources of variations	d.f.	Mean sum of square			
		5.4.84	15.4.84	25.4.84	5.5.84
Replication	2	3.62*	23.84**	1.59	35.28
Treatment	17	10.67**	65.08**	115.71**	71.28**
I	1	42.66**	590.04**	954.24**	740.74**
N	2	24.96**	127.93**	191.62**	78.24**
M	2	41.46**	119.26**	306.46**	142.57**
IxN	2	0.22	0.59	1.41	1.24
IxM	2	1.05	1.76	3.24	0.57
MxN	4	0.07	3.02	1.71	3.15
IxMxN	4	0.70	0.48	0.15	3.32
Error	34	1.00	3.34	5.45	12.50

Appendix- XXX Analysis of variance of average height (cm) of potato on different dates during 1985

Sources of variation	d.f.	Mean sum of squares				
		13.2.85	233.85	2.4.85	12.4.85	22.4.85
Replication	2	3.55*	10.14	19.64*	17.16	11.61
Treatment	17	15.35**	82.13**	128.41**	147.93**	151.42**
I	1	66.66**	633.79**	1162.04**	1261.50**	896.29**
N	2	75.37**	95.68**	232.89**	367.16**	247.53**
M	2	16.62**	237.35**	233.89**	232.66**	581.86**
IxN	2	1.29	1.59	11.55	9.50	0.28
IxM	2	1.54	34.13**	16.79	8.00	1.59
MxN	4	0.68	6.01	3.46	0.66	2.04
1xMxN	4	0.48	0.23	4.43	3.99	1.78
Error	34	1.07	4.26	5.61	7.46	7.49

Appendix-XXXI Analysis of variance of number of branches per plant at different dates during 1984.

Sources of variation	d.f.	Mean sum of squares			
		5.4.84	15.4.84	25.4.84	5.5.84
Replication	2	0.90	1.68	2.24	1.77
Treatment	17	4.76**	7.40*	5.82*	5.95**
I	1	13.50	29.62**	25.35**	24.13**
N	2	20.24**	11.62	9.85*	10.77**
M	2	8.90	27.79**	21.90**	23.10**
IxN	2	1.05	0.97	1.85	2.20
IxM	2	0.72	1.69	0.35	0.06
MxN	4	0.04	1.52	0.07	0.14
IxMxN	4	1.36	1.51	1.35	1.08
Error	34	3.47	3.36	2.35	1.69

Appendix-XXXII Analysis of variance of number of branches per plant at different dates during 1985

Sources of variation	d.f.	Mean sum of squares				
		13.3.85	23.3.85	2.4.85	12.4.85	22.4.85
Replication	2	9.18**	16.12**	9.40**	4.79*	5.38**
Treatment	17	12.73**	9.62**	7.28**	6.20**	6.75**
I	1	37.50**	32.66**	39.18**	29.62**	37.50**
N	2	33.79**	15.57**	8.90**	7.35**	9.55**
M	2	47.57**	36.12**	17.79**	22.74	23.16**
IxN	2	1.05	2.72	1.68	1.35	0.66
IxM	2	0.50	2.06	1.46	0.96	0.72
MxN	4	2.74	2.24	0.71	2.57*	2.13*
IxMxN	4	0.55	2.27	5.55**	0.18	0.13
Error	34	1.65	1.38	1.36	0.95	0.64

Appendix - XXXIII Analysis of variance of number of leaflets per plant at different dates during 1984

Sources of variation	d.f.	Mean sum of squares			
		5.4.84	15.4.84	25.4.84	5.5.84
Replication	2	110.79	313.01*	167.57	132.24
Treatment	17	598.55**	1398.97**	3012.15**	3346.83**
I	1	1004.16**	4685.35**	12090.07**	12573.63**
N	2	1680.90**	4217.24**	10519.90**	12749.01**
M	2	2540.74**	5014.01**	8509.79**	8931.68**
IxN	2	5.05	17.79	67.90	66.46
IxM	2	69.55	86.90	203.57	120.12
MxN	4	48.57	12.79	35.88	46.01
IxMxN	4	46.11	93.52	92.66	100.96
Error	34	73.01	69.68	103.69	92.47

Appendix - XXXIV Analysis of variance of number of leaflets per plant at different dates during 1985

Sources of variation	d.f.	Mean sum of squares				
		13.3.85	23.3.85	2.4.85	12.4.85	22.4.85
Replication	2	4.22	121.35	217.79	109.79	126.38
Treatment	17	474.15**	1164.59**	2538.26**	4304.67**	4376.99**
I	1	1213.62**	4125.62**	11704.16**	19078.24**	20768.16**
N	2	381.50**	2305.68**	6904.24**	12808.79**	12892.16**
M	2	2760.05**	5025.90**	8178.12**	13213.63**	13107.16**
IxN	2	56.69	91.13	64.50	115.57	57.16
IxM	2	27.46	11.91	11.05	62.51	90.16
MxN	4	53.97	133.24	180.32	318.51**	242.66*
IxMxN	4	44.94	67.57	102.30	106.52	94.16
Error	34	41.43	137.46	194.91	71.16	59.38

Appendix- XXXV Analysis of variance of tuber size distribution (the values are percentages of pooled yield of 1984 and 1985)

Sources of variations	d.f.	Mean sum of squares		
		Small grade	Medium grade	Large grade
Replication	2	99.52*	174.07*	276.51**
Treatment	17	121.28**	70.82	290.75**
1	1	143.66**	81.54	441.87**
N	2	16.28	143.60	232.59**
M	2	596.98**	110.56	1203.42**
1xN	2	46.93*	3.85	51.89
1xM	2	137.83**	45.43	338.43**
MxN	4	30.03	84.59	142.99*
1xMxN	4	50.47*	44.28	69.06
Error	34	14.29	46.50	42.36

Appendix- XXXVI Analysis of variance of potato tuber yield (q/ha)during 1984, 1985 and pooled yield.

Sources of variations	d.f.	Mean sum of squares		
		1984	1985	Pooled
Replication	2	4380.47**	281.44*	1629.72**
Treatment	17	7024.97**	8264.48**	7146.79**
1	1	81369.82**	50041.53**	64756.71**
N	2	6800.10**	5558.65**	5878.86**
M	2	7899.96**	29831.51**	17107.38**
1xN	2	1561.72*	498.05**	764.65**
1xM	2	2300.89**	4055.86**	2643.06**
MxN	4	127.14	1711.81**	651.85**
1xMxN	4	105.18	929.82**	335.84
Error	34	335.52	53.92	133.86

Appendix- XXXVII Analysis of variance of dry matter(q/ha) of haulm of potato during 1984 and 1985

Sources of variations	d.f.	Mean sum of squares		
		1984	1985	Pooled
Replication	2	3.29*	12.53**	6.64**
Treatment	17	12.76**	18.01**	14.61**
I	1	28.77**	32.32**	32.06**
N	2	41.24**	79.78**	58.26**
M	2	43.48**	52.40**	46.02**
IxN	2	0.68	0.38	0.42
IxM	2	1.64	1.66	0.66
MxN	4	1.88	0.11	0.38
IxMxN	4	1.64	1.24	1.01
Error	34	0.96	1.15	0.55

Appendix- XXXVIII : Analysis of variance of Starch content, reducing and non-reducing sugar in tubers during 1984 and 1985

Sources of variations	d.f.	Mean sum of squares					
		Starch content		Reducing sugar		Non-reducing sugar	
		1984	1985	1984	1985	1984	1985
Replication	2	71.49	72.14	0.04	0.02	0.02	0.11
Treatment	17	72.49*	228.90**	0.06	0.09*	0.18**	0.24*
I	1	262.59**	131.94*	0.13	0.67**	1.03**	0.66*
N	2	376.54**	1418.95**	0.28	0.35**	0.14*	0.95**
M	2	8.50	182.53**	0.13	0.07	0.49**	0.47*
IxN	2	2.47	81.23	0.001	0.01	0.04	0.08
IxM	2	32.54	6.82	0.001	0.005	0.02	0.05
MxN	4	7.09	30.68	0.01	0.013	0.08	0.09
IxMxN	4	25.06	64.39	0.0005	0.01	0.08	0.007
Error	34	36.02	27.73	0.046	0.044	0.03	0.109