INFLUENCE OF WATER AND SPECIFIC ANIONS AND CATIONS ON PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Influence of water and specific anions and cations on physico-chemical and biological properties of soil" is a bonafied record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Influence of water and specific anions and cations on physico-chemical and biological properties of soil" is a record of research work done independently by Miss. V. Jaya under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

Long since it is aware that plant performance, in addition to being influenced by the inorganic status of the soil, is also profoundly affected by the microbiological, organic moisture, aeration and physical factors prevailing in the soil. Limitations of certain ions can overcome by the presence of some other ions. When potassium is limiting sodium may serve to extend its supply. Cope et al., (1953) have stressed the increased availability of potassium in some soils as a result of sodium application.

Sodium plays a role of major importance in soil plant relations, particularly in arid and semiarid regions. This monovalent cation plays an important role in drought situations. Drought is one serious problem which causes reduction in production potentials of most of the field crops. Water can be retained in soil by making use of sodium chloride which is a cheaper source. Besides sodium helps to improve the release and availability of certain nutrient elements. Exchangeable sodium in the soil is found to have some effect on hydraulic conductivity. This helps to retain more water in the root zone of plants. Sodium is beneficial for the growth of some plants.

Anions like phosphorous is found to increase the efficiency of certain major nutrients like nitrogen. The mycorrhiza population in the soil is controlled to same extent by the presence of phosphorous and sodium. Phosphorous improves the growth of plant up to a certain stage. It is a very important plant nutrient which helps in the metabolic activities.

Mycorrhizal association in the root zone, helps the plant availability and uptake of nutrients (Young, et al ~~Juany and Guo,~~ 1986). Similarly it brings about the drought resistance in the plants. Some cations like, calcium and magnesium influence the phosphorous solubilizing power of mycorrhiza.

Different moisture conditions present in the soil affect the plant nutrient availability and uptake. The physical properties are also influenced by the soil water. The nutrient movement in the soil is greatly controlled by the soil water.

The important physical properties of soil which influence the availability and uptake of nutrients are soil bulk density particle density, pore space, water holding capacity, aggregation, hydraulic conductivity, and soil temperature. All these properties, thus indirectly or directly influence the plant growth and development.

Phosphorous is found to have an effect on infection of the mycorrhiza, which cause a solubilizing effect on it and making it more available to plant. By improving the soil conditions the vesicular arbuscular mycorrhiza helps in water retention and improves moisture conditions. The effects of different levels of phosphorous, sodium and water on the physico-chemical and biological properties are not studied in relation to plant growth. The interaction effects of sodium, phosphorous and water are important, to study their influence on nutrient availability and uptake. Their interaction may bring out changes in physical properties also. The mycorrhizal percentage also may be affected by the interaction effects of sodium, phosphorous and water. Water stress is a situation created by the soil environment and atmospheric parameter. Different ways and means have tried long past to solve the problem of drought conditions. Various research findings show that sodium present in the soil, as well the mycorrhizal population have some part to play in creating drought resistance in plants. Whether it is through soil or plant, is a controversy among scientists. If it is through soil the water retention power of the soil might have increased. Or if it is in the plant, the plant might have acquired some adverse conditions. Any how the actual situations are yet to be studied. Thus viewing the importance of such an investigation the present study has under taken with the following objectives:-

1. The influence of different levels of phosphorous on the biometric, observations of plant physico-chemical properties of soil and on mycorrhizal population.

2. Impact of different levels of sodium on nutrient uptake, biometric characters, and physico-chemical properties of soil.

3. Evaluation of mycorrhizal percentage in relation to different levels of phosphorus, sodium and soil water.

4. Study of the interaction effects of phosphorus, sodium and water levels on the physico-chemical and biological properties of soil.

5. Efficiency of the plants to survive under drought situations under the influence of sodium, phosphorus and vesicular arbuscular - mycorrhizae

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Plant growth and development is very closely related to the soil conditions. Physical, chemical and biological properties have impact on plant growth from seed to yield stages. Moisture conditions which prevail in the soil is directly related to the water absorption by roots. Soil moisture has influence on nutrient availability and uptake by plant. Water availability depends on soil physical, chemical and biological properties. Soil moisture conditions prevailing, influence the soil micro organisms.

Anions like phosphate has influence on mycorrhizal infection through its effect on chemical properties of soil. The relevant aspects are reviewed under different topics.

2.1. Effect of physical properties on plant growth

Physical environments prevailing in the soil play a prominent role in plant growth. Directly or indirectly they influence the different stages of plant growth. Soil strength, soil moisture, temperature and aeration, affect plant growth and nutrient availability.

2.1.1. Effect of soil water

Flooding reduced longivity of green leaves and their nitrogen content. (Joshi and Dastane 1965, 1966).

Choudhary et al. (1971) reported that prolonged submergence of wheat reduced the protein content of grain.

The water absorption is also influenced by soil temperature through its effects on the viscosity of water and permeability of seed coat.

Pradhal et al. (1973) found that maximum root length in rice increased as the soil moisture tension was raised.

Maity (1975) observed that higher evapotranspiration rates were always associated with lower soil matric suction level (0.1 to 0.4 bar) and it gradually decreased with the increase of soil matric suction up to 0.8 bar.

Choudhary and Bhatnagar (1980) found a close correspondance between wheat root distribution and water extraction pattern.

Mali and Varade (1981) reported that emergence of rice seedlings in a clay soil decreased significantly with reduction in soil moisture content and increase in bulk density.

Zalawadia and Patel (1983) found that 75 per cent available soil moisture significantly outyielded the other levels with respect to growth, kernal production, shelling percentage, oil content and phosphorous uptake by the groundnut crop.

2.1.2. Effect of bulk density

Gupta and Abrol (1970) observed that with increased bulk density there is an appreciable increase in uptake and concentration of nitrogen and phosphorus and to somewhat lesser extent the concentration of potassium, sodium, calcium and magnesium under compacted conditions and in [illegible] regime.

Singh and Gupta (1971) reported that fertilizer response was maximum at optimum bulk density of 1.35 g/cc and reduced at higher or lower compaction. Interaction between compaction and fertility was found significant on number of ear bearing tillers, uptake of nitrogen and phosphorus.

Primary seminal roots were significantly shorter and shallower with the penetrometer resistance. The resistance of close packed sands, to root penetration and the further hardening effect of gravel highlight the importance of promoting root size pores to by-pass mechanical resistance (Vine &Lal, 1981).

Katoch <u>et al</u>. (1983) observed that soil compaction significantly reduced the yield attributes, yield and protein content of seed.

2.1.3. Effect of Aeration

Holder and Brown (1980) reported that when plants were subjected to prolonged low oxygen concentration, resulted in decrease of transpiration and root injury.

2.1.4. Effect of temperature

Budhewar and Omanwar (1980) reported that increase in extractable zinc with increase in temperature of incubation seems to be due to enhanced microbial activity and subsequent decomposition and release of organic zinc at high temperature.

Reddy and Mishra (1983) noted an increased rate of ammonia loss at higher temperature during first week after urea application.

The total yield of corn increased 4 to 6.4 fold, root growth 2.6 to 5.1 fold, phosphorus uptake 2 to 4 fold when temperature increased from 18°C to 25°C. (Muckay and Busher, 1984). Similar observation on phosphorus uptake was reported by Barrow (1979).

2.2. Effect of anions on physico-chemical and biological properties of soil

The varying concentrations of anions in soil may influence the physico-chemical and biological properties of soil.

2.2.1. Concentration of anions and soil physical properties.

When the concentration of anion increases or decreases in the soil it may influence the physical properties in different ways. Various investigations were conducted to analyse the effect of anions on soil water, temperature, bulk density, etc.

Nair *et al.* (1966) reported that the apparent specific gravity is found to be a very convenient measure for available phosphoric acid and available potash in soils.

Singh and Gupta (1971) observed that interaction between compaction and fertility was significant on uptake of nitrogen and phosphorus.

Lutz and Haque (1975) observed that water retention at 5 bars alternately increased and decreased with increasing rate of phosphorus, but did not always exactly parallel in the case of changes in charge, hydration and swelling. The highest rate (1,600 ppm) caused a significant decrease in the five and fifteen bar percentages in all instances except the H_3PO_4 on kaolinite. Modulus of rupture was significantly reduced by source of P.

Gattani et al. (1976) through various experiments found that Phosphorus fertilizer had a beneficial effect on aggregation. White et al. (1976) observed that soil nitrogen and bulk densities increased and available phosphorus decreased in eight years of cultivation.

Eleizalde (1977) reported that the finer particles showed higher values for total, organic and inorganic phosphorus than particles greater than 50 micron.

Mandal and Khan (1977) found that changes in soil bulk density and water content have been shown to significantly influence phosphorus diffusion in soils. Singh and Jones ~~et al.~~ (1977) concluded from their experiment that there is much effect of temperature on the solubility and subsequent availability of phosphorus to plants.

Hira and Singh (1979) found that diffusion coefficient of phosphorus increased with increase in bulk density from 1.25 to 1.70 g cm^{-3}.

Barrow (1979) observed that phosphorus absorption on soil particle was exothermic. Karpachevskii et al. (1980) from their laboratory experiment showed that increasing the temperature from 4 to 40°C increased almost three fold the amount of P_2O_5 absorbed by anionite from sand.

Shanmuganathan and Oades (1983) found that the addition of phosphate and fulvate to soil samples with a net charge zero, lowered the zero point of charge producing particles with a net negative charge. This increased the amount of dispersible clay present from 0 to 90 per cent by weight of soil. The sorption of phosphate and fulvate by soil samples with a net positive charge reduced the zero point of charge and caused flocculation of dispersed clay. Treatments which produced dispersed clay, led to increased bulk densities, plastic limits and moduli of rupture but lower porosities, water holding capacities and hydraulic conductivities.

Mackay and Barber (1984) noted that the temperature affects each of the mechanisms involved in phosphorus uptake by corn.

Application of $(NH_4)_2 SO_4$ and Na_3PO_4 to the treated soil increased the bulk density, but reduced the water holding capacity. Phosphate given together with organic matter increased the water holding capacity and reduced the plasticity (Adhikari et al. ,1986).

Sah and Mikkelsen (1986) reported that phosphorus sorption capacity of soil increased with increasing temperature as well as with prior flooding. The bonding energy of sorption, calculated from the Langmunir isotherm, also increased with both temperature and prior flooding of soils. The apparent heat sorption reaction calculated with Freundlish isotherm and Van't Hoff's equation increased due to prior flooding of soil.

2.2.2. Anions and soil chemical properties

Anions are found to have great influence on soil chemical properties.

Gillman and Fox (1980) observed an agronomically significant increase in CEC of the surface horizon with increase in super phosphate application. As a result the leaching of applied nutrients like calcium, magnesium and potassium was retarded and greater quantities of these cations were present in the 0-50 cm profile than in the plot receiving no phosphorus, despite the fact that more cations were removed from the phosphorus treated plots by crops grown in succession.

Pal and Broadbent (1981) found that concentration of calcium and magnesium in the column effluents were higher with NH_4^+ sewage than with NO_3^- sewage. Magnesium was eluted to a greater extent by the nitrified sewage.

Prasad and Molto (1982) observed that the CEC increased in proportion to phosphorus retension by the soils. Removal of soluble aluminium, following phosphorus sorption brought about further increases in the CEC.

Significant cadmium sorption by the phosphate free oxide sample occured at pH level below the oxide zero point of charge, indicating that the sorption was sufficiently energetic to overcome some electrostatic repulsion. The Langmuir sorption constant for cadmium was increased by such enrichment (Skuo and Mcneal, 1984). Westerman <u>et al</u>. (1984) also found increased uptake of nitrogen, phosphorus and potassium when phosphorus is applied.

Stumpe <u>et al</u>. (1984) reported that addition of urea with phosphates slightly decreased ammonia loss from 17.0 to 12.2 per cent of the applied nitrogen on a highly calcarious soil. The relative savings of urea nitrogen were much higher in low calcium carbonate soils.

Peinemann and Vandeoli (1985) observed that sorption of phosphate was affected by the exchangeable cations and was increasing with increasing valency of cations indicating that the more compact the diffuse layer, the greater the phosphate sorption. It is proposed that the CEC of the soil might be influenced by phosphate sorption.

Ligand exchange has been described as the mechanism of the phosphate surface hydroxyl reaction (Gold berg and Sposito 1985). This includes absorption and desorption kineties of hydroxyl ion release. The addition of water favour formation of a monodentate surface complex.

Mahimairaja et al. (1986) reported that long term application of NPK fertilizers significantly increased the hydraulic conductivity of a vertisol. Soil porosity, aggregation and hydraulic conductivity were increased and bulk density decreased by the combined application of NPK fertilizer and cattle manure.

Shang and Bates (1987) found that plant zinc concentration decreased with increasing soil pH and increasing soil or fertilizer phosphorus.

Smille et al. (1987) observed that a high proportion (80%) of the added phosphorus could be recovered by water extraction when exchangeable calcium was replaced by sodium.

Zsoldos *et al.* (1987) found that the absorption of 2.4D by roots of rice seedlings was markedly increased in a phosphorus deficient nutrient solution compared with complete nutrient solution or a solution defecient in nitrogen, potassium or sulphur.

2.2.3. Anions and soil biological properties

Soil biological properties especially vesicular - arbuscular mycorrhizal infection was greately influenced by concentration of various anions present in the soil.

Islam *et al.*, (1980) observed that rock phosphate application reduced the degree of infection of mycorrhizal fungi without affecting plant growth in the field. In pot culture, nodulation, nitrogen fixation and utilization of rock phosphate were increased by inoculation with mycorrhizal fungi.

Omusu and Wild (1980) reported that inoculation of lettuce, onion and clover with VAM fungus (*Glomus mosseae*) increased plant yields and phosphate uptake in three soils that had been depleted in phosphate. The lower specific activity in lettuce and clover has been attributed to greater release of slowly exchanging phosphate caused by the high uptake of phosphate by the mycorrhizal plants.

Howeler *et al.* (1981) found that inoculation with mycorrhizal roots had a positive effect on phosphorus concentration of plant tissue and or plant growth even at the lowest phosphorus concentration in solution.

Menge *et al.* (1981) reported that mycorrhizal dependancy of troyer citrange was positively correlated with soil pH and inversely correlated with extractable soil phosphorus.

Yawney (1982) reported that soil phosphorus, soil pH and mycorrhizal condition significantly influenced nutrient levels in plant parts.

Same *et al.* (1983) reported that increasing phosphorus supply decreased the percentage of root length converted to mycorrhizae. Small additions of phosphorus to several defecient plants increased the percentage root length infected possibly by stimulating the growth of the mycorrhizal fungus.

Plenchette (1984) concluded that mycorrhizal fungal development in the roots depended on the internal phosphorus concentration when external phosphorus concentration was low and on external phosphorus concentration when internal phosphorus concentration was low.

Frankland and Harrison (1985) observed that infection of ectomycorrhizae in *Betula*, vesicular-arbuscular mycorrhizae in Acer were highly correlated with several soil factors like pH, organic matter, phosphorus and iron.

Johnson and Hummel (1986) found that improved phosphorus uptake by mycorrhiza inoculated severinia plants, appeared at least partially responsible for increased growth compared to non-VAM plants under conditions of high soluble salts and pH associated with high field montmorillonite clay.

The vesicular-arbuscular mycorrhizal infection of root samples of mixed vegetation was negatively correlated with both pH and phosphorus aluminium. (Noordwiijk and Hairiah, 1986).

Pacovsky and Fuller (1986) found that phosphorus concentration was significantly lower in VAM plants at weeks six and nine as compared to non VAM soyabean suggesting phosphorous input in VAM plants was immediately used for new growth. Total phosphorus input for VAM plants was linear over 21 weeks and the average rate of phosphorus uptake for these plants was 0.19 mg Pd^{-1}. Estimated specific phosphorus uptake rates (SPUR) for the mycorrhizae (VAM roots) were twice that of the control roots.

Sreeramalu and Bagyaraj (1986) reported that *Glomus fasciculatum* caused maximum increase in growth, phosphorus, and zinc content and influenced the flowering and yield of chilli plants.

Young *et al*., (1986) observed that vesicular-arbuscular mycorrhiza can enhance the uptake of the fixed soil phosphorus. The efficiency of utilization of various forms of phosphorus by mycorrhizal plants depend on the species of mycorrhizal fungi present and also on the soil types.

Levels of mycorrhizal infection on *Leucaena* roots increased as the concentration of phosphorus was raised from 0.002 to 0.153 Mg ml^{-1}. Higher levels depressed mycorrhizal infection but the level of infection was never less than 50 per cent. Mycorrhizal inoculation significantly increased phosphorus uptake and dry matter yield at all levels of soil solution phosphorus (Habte and Manjunath, 1987).

2.3. Effect of cations on physico-chemical and biological properties of soil

Cation absorption and interaction in exchange complex defenitely influence the soil physical properties, chemical reactions and biological characteristics of the soil. On the other hand cationic transformations and exchange are influenced by the physico-chemical and biological properties of soil.

2.3.1. Cations and soil physical properties

Cations have great effect on most of the soil physical properties such as hydraulic conductivity, soil structure etc.

Reid *et al.* (1949) reported that soil aggregation was significantly higher in saline soils than in normal soils. These soils are found to be generally flocculated and highly permeable and do not contain exchangeable sodium ions to any appreciable extent (Richards 1954).

Bodman and Fireman (1950) observed that high sodium water (Ca/Na = 0.17) of concentration 4000 ppm increased the exchangeable sodium in soil upto 30 per cent and greately reduced permeability.

Richards (1954) concluded that soils which contain appreciable amounts of exchangeable sodium ions are in a dispersed condition and have generally poor soil physical characteristics. This findings has been confirmed by Gupta and Narain (1971) Singh (1972) and Marwaha (1972).

Talati et al., (1959) showed that in the absence of high amounts of soluble salts in Rajasthan soils, exchangeable sodium was correlated with soil texture. When exchangeable sodium exceed 9 per cent of the CEC, the percolation rate markedly decreased. A reduction in permeability or hydraulic conductivity with increase in exchangeable sodium ions in the soil or sodium ion. Concentration in permeating water has also been reported by Govinda Iyer (1957) Klaga (1966) Sharma (1972).

Mohammed and Kamper (1962) reported that the presence of salts affected the loss of water from the soil by evaporation and transpiration. It was also noted that the water holding capacity decreased with the salt content and vice versa.

Kanwar and Deo (1969) reported that hydraulic conductivity decreased as the ratio of monovalent/divalent cations increased.

Gupta and Abrol (1970) concluded that increased bulk density resulted in appreciable increase in concentration of nitrogen and phosphorous and to somewhat lesser extent is the concentrations of potassium, sodium, calcium and magnesium.

Lodha and Seth (1970) reported that potassium decreases with the increase in size of the particle. The clays of undifferentiated alluvium and grey brown soils contain very high amount of total potassium and the predominant type of clay appears to be illite.

~~Mahendra~~ Singh (1970) showed that the finer fraction of the soil was significantly correlated with total and immediately available boron.

Satyanarayana and Ghildyal (1970) found that nitrogen and magnesium uptake increased with increase in bulk density up to 1.63 g cm^{-3} but decreased with subsequent increase in bulk density. The concentrations of iron, manganese, calcium, phosphorus and sodium increased in the plant material as the bulk density increased from 1.4 to 1.83 g cm^{-3}.

An increase in exchangeable sodium percentage was accompanied by a marked decrease in hydraulic conductivity

(Dixit and Lal, 1972) Govinda Iyer (1957) Klagga (1966) and Sharma (1972).

Singh (1972) pointed out that sodic soils possess extremely slow to very slow hydraulic conductivity values, because of their dispersed nature. Similar observation has also been made by Mc Intyre (1979).

Pandey and Pathek (1975) studied the physical properties of normal and salt affected soils and found that high sodium saturation increased bulk density and decreased non capillary porosity, resulting in low hydraulic conductivity.

Acharya and Abrol (1977) reported that higher base intake rute and increased retension at low suctions resulted in greater profile water storage at low ESP. Improvement in transmission characteristics resulting from lowered ESP was reflected in the drying pattern of soil. The first stages of drying was delayed in low ESP treatments compared to the high ESP treatments, because of regular movement of water from lower layers to the surface to meet evaporation demand.

Boldyrev et al., (1977) reported that prolonged irrigation with mineralized waters from the ingulets canal resulted in more compact, dispersed and fine textured soils with reduced aggregate stability and permeability. The adverse effects were explained, not only by mechanical action but also by the dispersing effect of sodium ions, the content of which in the irrigation water varied from 40 to 70 per cent of the total cations.

Abrol et al. (1978) observed that increasing exchangeable sodium percentage (ESP) moisture retension increased at soil water suctions greater than about 0.2 atm, while at lower suctions more moisture was held in soils of low ESP. Infiltration rate, soil water storage, hydraulic conductivity and soil water diffusivity underwent a sharp decrease when ESP was higher than about 15. Dispersion and displacement of dispersed particles is considered to be the chief mechanism responsible for observed reduction in the transmission characteristics. The depth to which dispersed particles are displaced decreases with increasing dispersibility resulting from high ESP values.

Acharya et al. (1978) showed that ESP significantly affected the magnitude and pattern of water content changes in the profile following evaporation. The total surface water loss under evaporative demands was higher from the low ESP soil than from the high ESP soil, because the hydraulic conductivity was greater.

Dane (1978) studied that the calculated effective soil porosities were used to predict hydraulic conductivity values, corresponding to a solution of decreasing electrolyte concentration or increasing SAR values.

Pupisky and Shainberg (1979) in their data indicated that at high ESP and salt concentration above 0.01N, Swelling of clay was the main mechanism responsible for the hydraulic conductivity decreases At low ESP and very dilute soil solution dispersion and clay migration within the conductivity pores were the main mechanisms responsible for plugging the soil pores.

Agassi <u>et al</u>. (1981) showed that the infiltration rate was more sensitive to the sodicity of soil and to the electrolyte concentration of the applied water than was the permeability of the underlying soil. Crust formation is due to two mechanism (i) a physical dispersion of soil aggregates caused by the impact action of the rain drops and (ii) a chemical dispersion which depends on the soil exchangeable sodium percentage (ESP) and electrolyte concentration of the applied water.

Berkheiser (1981) concluded that the amount of water adsorbed by the cation-humic complexes were directly related to the absolute standard enthalpy of hydration on monovalent cations in the series lithium$^+$, Sodium$^+$, Potassium$^+$ and Cesium$^+$. But the tetramethyl ammonium (TMA$^+$) humic complex adsorbed more water than expected, based upon the absolute standard enthalpy of hydration of TMA^+. The amount of water adsorbed by humic materials saturated with monovalent cations depend on the nature of saturating cation and strength of interaction of the cation with humic surface.

The sodium and organic matter addition to soil through the waste water were found to interact in their effects on the active surface of soil particles. As a result of this interaction, drainage of heavier soil, impaired during effluent irrigation, improved by subsequent drying (Burns and Rawitz, 1981).

Shainberg et al. (1981) observed that when the salt concentration is 3.0 meq l^{-1}, the hydraulic conductivity and clay dispersion decrease if the exchangeable sodium percentage (ESP) values exceed 12. In distilled water, clay dispersion and hydraulic conductivity decrease at ESP values as low as 1 to 2 per cent.

Cass and Summer (1982) proposed an emphirical sodium stability model which express the relationship between the slopes of the threshold concentration curves as a function of the degree of hydraulic conductivity reduction. This model provides a means of evaluating both, the suseptiability to hydraulic conductivity reduction and the degree of hydraulic conductivity change, as the percolate concentration.

changes. They also related the slope of sodium sensitivity model to the smectite content, cation exchange capacity and specific surface of pedal, non verticsol soil through log log relationship. Soils with low specific surface, low CEC and little smectite and or sufficient sesquoxide to inhibit swelling tend to be most stable in the presence of mixed Na/Ca solutions.

Hadas and Frenkel (1982) reported that the infilteration rates of the gypsum treated plots were higher than the non treated plots, for each field and the infiltration rate of the soil irrigated with sodic-saline water for 8 years was greater than the infiltration rate of field irrigated for two years.

Kazman et al. (1983) reported that the infiltration rate of four soils was very sensitive to low levels of ESP where the hydraulic conductivity (HC) of these soils was less sensitive. The presence of lime in the soils was effective in preventing hydraulic conductivity decreases due to low levels of exchangeable sodium. Lime was not effective in maintaining the infiltration rate of the calcarious soils, phosphogypsum prevented the sharp drop in infiltration rate of the soils at low levels of ESP.

Reddy and Mishra (1983) observed an increased rate of ammonia loss at higher temperature during first week after urea application. Bresler et al., (1984) found that soil salinity (EC) accounted for only 10-15 per cent of the variability of saturated hydraulic conductivity, texture (per cent sand) explained 25 to 45 per cent of the conductivity variability and 10 to 15 per cent of the variability were explained by the interaction between salinity and texture.

Gal et al. (1984) attributed the crust of sandy loam with ESP 1.0 consisted of a compacted skin seal, to the mechanical impact of rain drops. Little clay movement or development of a "washed in" layer was observed under these condition. At ESP greater than 1.6 the crust consisted of naked sand and silt grains over a clean washed in layer.

Black and Abdul Hakim (1985) found an increase in SAR from 0 to 44 resulted at high EC (5 meq l^{-1}), in a 25 per cent decrease in relative permeability but there was no significant difference between soils at each SAR. At low EC (0 meq l^{-1}) an increase in SAR resulted in an average relative permeability decrease of 70 per cent. The organic matter maintain structural stability at moderate Na^+ levels.

Adhikari et al (1986) observed that the presence of Calcium and magnesium with organic matter increased the water holding capacity, plasticity and aggregate size. Copper and zinc reduced the aggregate size but increased the water holding capacity.

Irurtia and Peinemann (1986) found that in samples of sandy loam or clay loam textures, when the total salinity passes from high to low values, maintaining a high SAR, the hydraulic conductivity become practically zero, the percolates had pH values up to 8.5 and contained organic matter and clay in suspension as a consequence of the high dispersion. In loamy sand texture the migration of clay particles also took place but there was a slight increase in hydraulic conductivity.

Karim and Sulaiman (1987) reported that decalcification with dilute acid, shifted particle size distribution to finer texture classes and increased the moisture content of most of soils over a wide range of suctions and at the liquid and plastic limits.

2.3.2. Cations and soil chemical properties

Various cations present in the soil influence the chemical reactions of the soil.

Singh and Sharma (1970) found that silt + clay, Calcium carbonate, pH and calculated values of ESP, SAR and SSP of saturation extract were to be higher in saline water irrigated soils as compared to unirrigated ones, while the reverse trend was observed with pore space.

Nitant (1974) reported that both high pH and salinity reduced nitrogen mineralization to a great extent.

Paliwal and Maliwal (1975) reported that mineralized and available nitrogen and organic matter content decreased with the increase in the ESP and pH of the soils. The uptake of nitrogen and phosphorous was negatively correlated with the salinity of soils.

By mixing phosphated soil with solutions of chloride salts, in calcium chloride the rate of desorption of phosphate was found to be inversly propotional to the calcium concentration. Desorption was faster in .01 M magnesium chloride than in 0.01 M Calcium chloride and faster in .03 M Sodium chloride than in either magnesium or calcium chloride. A range of monovalent cations formed a sequence from fastest to slowest of lithium^{+} > sodium^{+} > ammonium^{-} > potassium^{+}, rubilium^{+} > cesium^{+}. The escaping tendancy of the phosphate was decreased when the cations which balanced the negative charge on the absorbed phosphate were close to the surface. Thus identity and concentration of the cations had a large effect on the concentration of phosphate when the solution soil ratio was was small (Barrow and Shaw, 1979).

Rahman and Rowell (1979) confirmed that sodium - magnesium montmorillonite and a montmorillonite soil behaved identically to the sodium - calcium systems at the same ESP and electrolyte concentration. At the same SAR the higher ESP in the sodium - magnesium systems caused greater changes than in the sodium - calcium systems. At the same SAR, the higher ESP in all the sodium - magnesium systems apart from vermiculite increased the differences, but for vermiculite with a lower ESP, the differences were reduced.

Bladel and Gheyi (1980) reported that calcium was selectively adsorbed over sodium and to a lesser extent over magnesium. Enthalpy and entropy changes were negative for the substitution of calcium by sodium.

Devitt et al. (1981) reported that increasing the salinity of the irrigation water increased the concentration of both sodium and potassium in the saturation extracts and greately increased the accumulation of sodium in leaves of wheat plant. The best indicator of the potassium - sodium ratio found in leaves at harvest was the product of potassium-sodium in soil solution and the root length density.

Fenn et al. (1981) noticed that ammonia volatalization from soils after surface application of urea or inorganic nitrogen were reduced by calcium and magnesium nitrates or chlorides, sulfates were less effective. Suppression of amonia loss was a result of two chemical reaction (i) Precipitation of carbonate by calcium thus preventing permanant $(NH_4)_2\ Co_3H_2O$ (AC) formation and (ii) Calcium depression of soil pH by decreasing the dissociation of the $CaCO_3 - Ca(OH)_2$ buffer system. Soil pH values as low as 6.5 were recorded in calcarious soil and 3.9 and 4.5 in the acid soils after addition of calcium. Soil pH values in the presence of calcium reached approximate nutrality in 24 hours even in acid soils. Soil pH without calcium but with ammonium carbonate plus calcium reduced the pH of calcarious soil to 5.3 and raised it to 5.7 in acid soils.

Increased potassium application increased the cytosol calcium, magnesium and phosphorus but decreased the sodium content. (Lynd et al., 1981).

Oster et al., (1980) reported that the flocculation value of calcium - montmorillomite increased rapidly with, small amounts of exchangeable sodium^{+}. The flocculation values for calcium and sodium illite increased linearly with sodium. Vander-Waals attraction forces are mainly responsible for the flocculation of Cu-montmorillomite and Illite systems.

Stout and Baker (1981) found the differential adsorption of potassium as the controlling factor in the uptake of Mg by corn seedlings.

Suarez and Frenkel (1981) reported that sodium hydrolysis exceeded calcium hydrolysis for soil clay fraction where-as sodium and calcium hydrolysis rates were about equal for the montmorillonite due to the dissolution of other silicates in the soil clays. Sodium kaolinite hydrolysed so rapidly that it could not be prepared free of chlorine without almost total loss of exchangeable sodium.

Dufey et al.. (1982) found that the perclet number (P) for chlorine (Pcl) was to decrease markedly when the exchangeable sodium percentage (ESP) increased from 0 to about 20 per cent. P Na and Pca were almost not affected by changing ESP. The following sequence was observed P Ca P Na Pcl. The discriminatory mixing power of soil towards the three ions likely results from changing size of montmorillonite tactoids and from demixing of adsorbed sodium and calcium cations.

Nadler and Magaritz (1982) observed a portion of the dissolved HCo_3 of sodium carbonate in sodic soils, reacts with calcium $^{2+}$ initially present in the soil and is immediately precipated as calcium carbonate.

Wallace et al. (1982) reported that in Atriplex polycarpa SO_4^{2-} decreased calcium and magnesium concentrations by applying Sodium Sulphate. In Atriplex canescens leaves contained less sodium, total cations, chlorine, sulphur and Silicon but more nitrogen than did those of Atriplex polycarpa Chloride decreased nitrogen concentrations in leaves of A. polycarps by applying sodium chloride.

Replaceability of interlayer potassium$^+$ decreased as rubidium$^+$ content increased to 1 per cent in the exchangeable sites (Bamber and Carlson, 1984).

Devitt et al., (1984) found the ability of root system to tolerate high levels of soluble salts and in particular high levels of sodium$^+$ is partially due to compensatory uptake of water and ions in the most favourable regions. Sodium-22 results indicated that the regions closest to the surface were the most active in terms of sodium$^+$ uptake.

Fletcher et al., (1984) found from the exchange isotherms for magnesium that, there is some preference on the soil for calcium over magnesium.

Rappaport and Axley (1984) reported that one part urea with one part or greater of potassium chloride (by weight) as a fertilizer solution reduced ammonia losses from 42 per cent to 46 per cent or even, less.

Gupta et al. (1985) observed that at 29.3 ESP diammonium phosphate was a better source of phosphorus than monocalcium phosphate but at 50.2 ESP monocalcium phosphate out yielded diammonium phosphate. Nitrophosphate having 57.5 per cent water soluble phosphate was only 51.5 per cent efficient, compared with diammonium phosphate. At higher levels of phosphorus wheat plants exhibited copper defeciency.

Classens (1986) found that relatively high concentration of NH_4 were tolerated, with the addition of sodium (3 meq dm^{-3}) to the nutrient solution even high NH_4 concentrations (7 meq dm^{-3}) could be tolerated. Relatively high total salt concentration could be tolerated if the phosphorus concentration was within acceptable limits.

Black *et al.* (1987) established that on air dry soil hydrolysis of ammonia was slow.

2.3.3. Cations and soil biological properties

Soil biological properties, to some extent are influenced by the various cations present in the soil.

Lalitha Batra and Bharadwaj (1981) found that vegetative growth was adversly affected due to increasing ESP. At higher ranges of sodicity there was marked reduction in drymatter yield, number of nodules and nitrogen content of all the legumes except daincha which was found to be distinctly tolerent to high exchangeable sodium. Only daincha and Indian clover can grow, nodulate at ESP 70. In other plants substantial growth and nodulation occured only up to ESP 34. The number of nodules declined more sharply than the dry matter yield. In the initial period despite plant growth, nodulation was found to be lacking at the highest level of ESP. Subsequent appearance of nodules showed inhibition of legume-rhizobia symbiosis due to excess exchangeable sodium.

Menge *et al.* (1981) observed a positive correlation between foliage concentration of magnesium in non mycorrhizal troyer citrange and mycorrhizal dependency.

Schultz *et al.* (1981) found that the growth of the nonmycorrhizal seedlings at the higher fertilizer levels was not sufficient to produce plantable seedlings for artificial regeneration.

Pacovsky (1986) observed that copper and zinc concentrations were always higher in vesicular arbuscular mycorrhizal plants while iron and manganese concentration were lower than in the equivalent phosphorus fertilized soyabeans.

Peter and Williams (1986) envisaged that processed water from shale industry containing increased concentration of calcium, magnesium, sodium, nitrate and ammonium as well as with high electrical conductivity if applied to the crops, result ~~result~~ reduced mycorrhizal activity in treated soils

Polonenko et al., (1986) noticed that salt stress may cause a significant reduction in the number of microorganism in a soil, a large portion of the microbial population can rapidly adopt to marked changes in salinity.

Rogers and Williams (1986) reported that cesium content was greater in the mycorrhizal treated soil than control. Cobalt content was increased 2.5 times than that of the control at the first harvest date.

Saif (1986) observed that NPK fertilizers slightly reduced spore numbers without affecting infection. Infection and spore population were increased by returning plant residue to the field. Potassium fertilizer increased infection on legumes.

Stahl and Williams (1986) reported that water from oil shale processing contain increased concentrations of calcium, magnesium, sodium, nitrate and ammonium, reduced mycorrhizal activity on the roots.

Strullu *et al.*, (1986) reported that the rate of uptake of phosphate from dilute solutions of KH_2PO_4 by fungus mycorrhiza was much increased if calcium or magnesium as chlorides was added to the solution but not if sodium or potassium was similarly added. The P/Ca ratio of granules was reduced in the presence of calcium and increased in that of magnesium. It is concluded that these divalent cations are incorporated into phosphatic granules and that their effect on phosphate uptake is related to the reduction in the soluble phosphate present in the cells rather than to their effects on the cell membrane.

2.4. Soil moisture conditions in relation to physico-chemical and biological properties of soil

Moisture conditions prevailing in the soil, have vital role in deciding the physical, chemical and biological properties of the soil. Soil mechanical properties, aeration and soil temperature are to a great extent depend on soil water. As well the nutrient availability, uptake and movement are controlled by various hydrological properties. Soil reaction is a water dependant factor. Many of the micro-organisms live in the soil are surviving on optimum moisture conditions.

2.4.1. Soil water and physical properties of soil

Soil moisture status has a great influence on soil physical properties like soil aeration, temperature etc.

Chibber *et al.* (1964) found that moisture equivalent and water holding capacity are significantly correlated to water stable aggregates.

Choudhary *et al.* (1971) reported that water absorption is also influenced by soil temperature through its effects on the viscosity of water and permeability of seed coat.

Ghildyal and Tripathi (1971) observed that thermal conductivity increased exponentially with the increase in degree of saturation. Volumetric heat capacity showed parabolic relationship with the degree of saturation. Thermal diffusivity also increased exponentially with increase in degree of saturation.

A high significant positive correlation between clay content and the moisture constants was observed by Velayudhan and Raj (1971). Organic carbon and CEC were also significantly correlated with the moisture constants.

Acharya and Gupta (1975) found that thermal diffusivity values increased with moisture content up to a particular wetness of soil and then the rate of increase decreased with further increase in moisture.

Gumbs and Warkentin (1975) reported that larger values for diffusivities and conductivities on wetting than on drying and generally larger in unconfined than in confined samples. The values of water tension, diffusivity and conductivity at any water content depend on the rate of wetting.

Gupta and Bhatia (1975) studied the behaviour of air permeability at various combinations of moisture content and bulk density and it was attributed to (a) reduction in air filled porosity with increase in moisture content coupled with swelling of solid phase at the expense of void space (b) Maximum swelling effects in the moisture content range of 22 to 36 per cent by volume at relatively low bulk densities.

A significant positive correlation was obtained by Talati <u>et al</u>., (1975) individually between soil moisture constants and, silt and clay content.

Skinner (1975) reported that under anaerobic incubation the type of nutrient added had little effect on stability. Aerobic incubation with glucose gave a larger proportion of stable aggregates than water.

Any drop in moisture content which caused the pores to drain produced a sharp decrease in the apparant self-diffusion coefficient (Barraclough and Nye, 1979).

Lawrence et al. (1979) found that critical point drying produced more shrinkage from p^F-1 more than half of which was atributed to loss of interlamellar water and rest to the collapse of pores larger than 10 μm and most of the plant available water was released by collapse of narrower pores and not by pore emptying.

Spoor and Godwin (1979) observed that the soils deform either in a compressive way or by brittle fissuring, depending upon the relative values of moisture content. The shear strength of the clay soils tested was more closely related to the soil moisture suction and to the amount of shrinkage which occured on drying than to the absolute dry bulk density.

Patel and Singh (1981) related increased bulk density with depth, and found that this depends on the soil water content at the time of compaction. Soil compaction increases the number of small pores at the cost of larger pores and conducts much less water per unit pore space. This intake rate and hydraulic conductivity of the soil decrease with compaction.

Sharma and Felitsiant (1983) found that the stratification enhanced the water retension of the layers at field capacity in soil having loam as overlying material.

A highly significant variation observed in the ODR values, when water table changed from 0.45m to 0.75m depth and to 0.15m depth (Bornstein *et al.* 1984).

Kemper and Rosenew (1984) reported that cohesion increased for several month after disruption in moist soils. Rate at which cohesion increased was slower in air dry soil, but continued for years.

Egashira *et al.* (1986) observed that the natural water content was a good indicator of 15 bar percentage, liquid limit, bulk density, water retension at RH 52 per cent and organic carbon content.

Olivier *et al.* (1986) showed that bulk density increased with depth and decreased with increasing water content.

Ploughing soil at high moisture contents caused a rise in penetrometer resistance and in bulk density and a decrease of macro pores as well as in oxygen concentration in the top soil and tillage pan (Maidl and Fischbeck, 1987).

2.4.2. Effect of soil water on chemical properties of soil

Soil water affects the availability of nutrients like nitrogen, phosphorus etc. in different ways.

Joshi and Dastane (1965) noticed that flooding reduced longivity of green leaves and their N_2 content.

Vyas and Motiramani (1971) reported that at the same phosphorus level, higher moisture per cent increased the availability of phosphorus. Minimum fixation was found at 60 per cent moisture level and maximum at 10 per cent moisture level.

Debnath and Hajra (1972) found that rate as well as magnitude of shift in the amounts of various phosphate fraction were enhanced by higher moisture level.

Mandal and Khan (1975) showed that continues waterlogged condition appeared to be beneficial for the availability of soil native phosphorus in acid soils. The alternate waterlogged - saturated condition was found to decrease the Al-P content in all the soils. Under continuous waterlogged and saturation treatments the soils poor in native Al-P content recorded an initial increase in Al-P content followed by a decreasing and then an increasing trend. While the soils comparatively rich in Al-P content recorded a progressive decrease. Shimpi and Savant (1975) reported that continuous submergence favoured ammonia retention in the soils.

Subramanyam and Mehta (1975) found that zinc availability was maximum under saturation, followed by flooding and field capacity in that order. Available iron and manganese were maximum under flooding, least under field capacity and intermediate under saturation. Application of zinc decreased the availability of iron and increased that of manganese, while iron addition decrease the available zinc content of soil.

Cameron and Posner (1979) reported that mineralization of the nitrogen of high C/N fraction was much greater in incubation under waterlogged anaerobic condition than under aerobic condition, yet for low C/N fraction there was little difference.

Hira and Singh (1979) noticed that phosphorus diffusion increased from 9.47×10^{-7} to 23.72×10^{-7} cm^2 Sec^{-1} with increase in soil water content from 7 to 18 per cent g g^{-1}.

Budhewar and Omanwar (1980) observed more solubility of zinc under high moisture. So more available zinc in submergence than field capacity condition. They also reported an increase in extractable zinc with increase in temperature of incubation.

Cassman and Munns (1980) showed that nitrogen mineralization declined linearly with water content. In contrast, these was a sharp decline between 0.3 and 2 bar treatments and a more gradual decline at higher matric suctions.

For airdry soil maximum solute concentration occured at the wetting fronts in sandy loam and silt loam but lagged behind the front in the loamy land. (Ghuman and Prihar, 1980).

Keren (1980) observed that the CEC of the montmorillonite hydroxy-Al complexes after drying was higher than the nondried systems at a pH above 7.5, whereas no difference was observed at the lower pH range (pH 5-6). The CEC and spacing for both the dried and nondried systems were highly correlated.

A pronounced increase in exchangeable NH_4^+ content was reported by Frye and Hutcheson (1981) when soils are dried particularly when oven dried. Ammonia is released from both organic and inorganic components during oven drying.

Keren and Gast (1981) reported that Boron adsorption in the nondried suspensions was completely reversible for both the sodium and calcium systems. There was a significant exchangeable cation effect, however at higher pH with the calcium system adsorbing the greatest amount of boron. Drying and rewetting of the clay suspension after boron addition not only increased the amount of boron adsorbed, but significantly reduced the reversibility of adsorption process.

Magaritz and Amiel (1981) found that the large amount of irrigation water applied enhanced the process occuring in the $Ca\ Co_3$ - HCo_3 - Co_2 system.

The extractable phosphorous was consistently lower in the 0 to 0.3 m depth for the high irrigation. At the lower depths there was a suggestion of higher irrigation but this effect was not consistent (Pratt and Lag 1981).

Russelle et al., (1981) showed that grain yield and nitrogen-uptake were highest with light frequent irrigation. Heavier infrequent irrigation decreased tracer nitrogen - recovery. Maximum fertilizer use efficiency was obtained with the low rate applied as a side dressing and with light frequent irrigation.

Sharpley et al., (1981) observed that for all soils the logarithem of phosphorus release (Pd) was linearly related to the logarithem of contact time (t) at any given water/soil ratio (w) and phosphorus amendment and to logarithem of 'w' at any given contact time and phosphorus amendment.

Skogley and Haby (1981) reported that soils high in extractable potassium have frigid (cool) temperature regimes, and ustic moisture regimes. Chemical measurements which relate to the quantity of potassium in soil apparently do not have an adequate cause and effect relationship in the availability of potassium to plants.

Schaff and Skogley (1982) reported that soil moisture (10, 17 and 28%) significantly influenced the diffusion of potassium, calcium and magnesium. The temperature and soil moisture interaction was significant for all three cations.

Sharpley et al. (1981) showed that an increase in incubation time, temperature, and in water content between 10 and 25 per cent resulted in a decrease in the amount of phosphorus desorbed. This was attributed to the effect of these variables on phosphorus sorption, by formation and stability of amorphos iron and aluminium complexes and calcium precipitates.

Mitra and Mandal (1983) observed that under air dried condition the amount of water soluble and exchangeable ferrous iron was practically nil in almost all cases where as the content of water soluble and exchangeable manganese was fairly high. The amount of manganese in this form recorded a marked increase after waterlogging the soils for one month.

Patel and Ghildyal (1983) reported that the inflow rate of nutrients was the maximum under unsaturated treatments and was higher with drainage treatments than under flooding and under recycling treatments.

Reddy and Shastry (1983) found that the movement of phosphorus was insignificant and it was up to 15 to 30 cm only under higher moisture levels. Potassium moved into the soil at all irrigation levels at irrigation water/cumulative pan evaporacion (IW/CPE) ratio of 0.60 to 1.05 and there was greater movement to lower depths (30-45 cm) under higher levels of irrigation. The crop uptake of phosphorus and potassium was greately facilitated at IW/CPE ratio of 1.05.

Significant increase in available phosphorus and phosphorus uptake was observed by Zalawadia and Patel (1983) in surface and subsurface soils with levels of irrigation.

Korentajer *et al.*, (1984) observed that increasing the percolation rate greately increased sulphate^{2-} leaching losses and decreased the apparant fertilizer recovery.

Mulvaney and Kurtz (1984) reported that N_2 and N_2O were evolved only if enough water was applied to increase the soil moisture content to a level above the 0.03 M Pa moisture percentage.

Norstadt and Porter (1984) found that soil nitrogen content was negatively correlated with soil temperature. Anaerobic soil conditions beneath a continuously maintained intact, moist manure pack would minimise possible nitrate nitrogen formation.

Pratt (1984) showed that the ratio of leached sodium from rootzone to input sodium in water was correlated with leaching factor.

Das and Mandal (1986) reported that the decrease in redox potential during fourty days was greatest under waterlogging. Extractable iron and manganese increased almost throughout incubation. Available nitrogen content showed an increase under waterlogging.

Rao and Narasimhan (1986) noticed that after four months of flooding the increase in CEC ranged between 22.7 and 1.11. In remaining soil there was a decrease from 0.4 to 12.7 per cent. In all soils AEC increased after two months of flooding but exchangeable calcium, potassium, and sodium contents of most soils increased afterflooding and only exchangeable magnesium showed a decrease.

Maidl and Fischbeck (1987) observed that very large differences in soil nitrate content between ploughing at low and high soil moisture content. Positive correlations were shown by the soil moisture contents with the clay, clay + silt, CEC/clay ratios and the organic carbon contents of the soil.

2.4.3. Effect of water on biological properties of soil

Soil water play a great influence on soil microflora and fauna and there by influence biological properties of soil.

Patten *et al*. (1980) showed that drying of soils markedly increases their capacity for denitrification of nitrate under anaerobic condition. Drying increases their capacity to denitrify nitrate under anaerobic condition by increasing the amount of soil organic matter readily utilized by denitrifying microorganisms.

Knight and Skujins (1981) noticed an increase in ATP concentration, in the water potential range -2 to -20 bars in the arid soils and was negatively correlated with exponential decreases in respiration rates for the same water potential range. It was concluded that the soil microflora may exhibit diverse physiological responses to water and consequently to available carbon source induced stresses in soils from environmentally different areas.

Mahler and Wollum (1981) found that soil water potential and soil texture play an important role in the survival of the four rhizobia isolated. Rhizobia population were always greatest at $^{-}0.3$ bars. Population were proportional to decreasing water potential to $^{-}15.0$ bar.

Keck et al. (1984) noticed specific nodule activity was enhanced by increasing the quantity of water applied at each irrigation and was adversly affected by increased irrigation by saline water.

Relatively at low soil moisture levels the beneficial role of mycorrhizae was reported by Reid (1984).

Many scientists like Dakessian et al. (1986) have obtained that soil water status and the mycorrhizal conditions interact in influencing plant growth.

Biomass - carbon released by water potential increase ranged from 17 to 70 per cent of total, was obtained by

Kieft *et al.* (1987). Respiration of biomass carbon - mobilized by water potential increase exceeded respiration of biomass - carbon made available by proceeding desication. Water potential increases associated with the wetting of dry soil may be a major catalyst for soil carbon - turnover.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment is carried out as a field experiment with Banana as test crop in the farm area at the College of Agriculture, Vellayani during March 1988 to April 1989.

3.1. Climatic conditions

Vellayani is situated at a latitude of 8.5°N, longitude of 76.9°E and at an altitude of 29 meters from M.S.L. During the period of investigation, there was as average rainfall of 108.5 mm. The average relative humidity maintained during the period is 71.7 per cent. Mean maximum day temperature of 32.2°C and a minimum of 23.6°C are recorded during the period of investigation.

3.2. Preliminary analysis

Soils are collected from the plots before planting suckers and analysed for physico-chemical properties. The results are given in table-1.

3.3. Field experiment

Plots located at a uniform topography are selected. The land is levelled uniformly and pits are taken for the planting of Banana suckers.

3.3.1. Design and treatments

The experiment is laid out in RBD with three levels of phosphorus, three levels of sodium and two levels of water.

Preliminary analysis

Table-1a Physical and mechanical properties of the preliminary soil

Physical properties								Mechanical analysis				
Moisture %	Bulk density g cm^{-3}	Particle density g cm^{-3}	Pore space %	Vol. Exp. %	Water holding capacity %	Mean weight diameter	Hydraulic conductivity Cm hr^{-1}	Coarse sand %	Fine sand %	Silt %	Clay %	Textural class
8.71	1.27	2.23	44.27	0.84	34.43	0.54	86.50	42.00	26.00	18.20	13.80	Loam

Table-1b Chemical properties of the preliminary soil

Organic carbon	Nitrogen		Phosphorus		Potassium		Calcium Cmols(+)kg^{-1}		Magnesium Cmols(+)kg^{-1}		Sodium Cmols(+)kg^{-1}	
	Available kgha^{-1}	Total %	Available kgha^{-1}	Total %	Available kgha^{-1}	Total %	Available	Total	Available	Total	Available	Total
0.24	168.25	0.006	8.25	0.0063	30.35	0.0005	0.0029	0.0033	0.0005	0.0089	0.00018	.00034

The layout of the experiment is shown in fig. 1. The treatment combinations are as follows:

1.	$W_1P_0Na_0$	10.	$W_2P_0Na_0$
2.	$W_1P_0Na_1$	11.	$W_2P_0Na_1$
3.	$W_1P_0Na_2$	12.	$W_2P_0Na_2$
4.	$W_1P_1Na_0$	13.	$W_2P_1Na_0$
5.	$W_1P_1Na_1$	14.	$W_2P_1Na_1$
6.	$W_1P_1Na_2$	15.	$W_2P_1Na_2$
7.	$W_1P_2Na_0$	16.	$W_2P_2Na_0$
8.	$W_1P_2Na_1$	17.	$W_2P_2Na_1$
9.	$W_1P_2Na_2$	18.	$W_2P_2Na_2$

Where

W_1 = First water level with 20 per cent depletion from field capacity.

W_2 = Second water level with 40 per cent depletion from field capacity.

P_0 = No phosphorus

P_1 = P_2O_5 @ of 90 g/plant/annum

P_2 = P_2O_5 @ of 115 g/plant/annum

Na_0 = No sodium

Na_1 = Sodium at the rate of 68 g per plant per annum.

Na_2 = Sodium at the rate of 136 g per plant per annum.

[illegible] [illegible]

[illegible]

N ← → S, E

R_1	T_2	T_{16}	T_6	T_{15}	T_7	T_{10}	T_{18}	T_3	T_8	T_{14}	T_5	T_9	T_{13}	T_1	T_{11}	T_4	T_{12}	T_{17}
R_2	T_{11}	T_{14}	T_{10}	T_{13}	T_5	T_{17}	T_4	T_9	T_7	T_8	T_{12}	T_{16}	T_6	T_{15}	T_3	T_{18}	T_2	T_1
R_3	T_4	T_{14}	T_3	T_{10}	T_1	T_8	T_{11}	T_{18}	T_9	T_6	T_{16}	T_2	T_{15}	T_{12}	T_{13}	T_7	T_{17}	T_5

1 = $V_1P_0NO_0$
2 = $V_1P_0NO_1$
3 = $V_1P_0NO_2$
4 = $V_1P_1NO_0$
5 = $V_1P_1NO_1$
6 = $V_1P_1NO_2$
7 = $V_1P_2NO_0$
8 = $V_1P_2NO_1$
9 = $V_1P_2NO_2$

T_{10} = $V_2P_0NO_0$
T_{11} = V_2P_0NO
T_{12} = V_2P_0NO
T_{13} = V_2P_1NO
T_{14} = V_2P_1NO
T_{15} = V_2P_1NO
T_{16} = V_2P_2NO
T_{17} = V_2P_2NO
T_{18} = V_2P_2NO

3.3.2. Application of treatment

All the treatments are replicated three times. Altogether there are 54 plots with three plants in each plot. Banana suckers var. Nendran of almost same age based on weight of suckers are planted as per the layout. Nitrogen and potassium are added as per the package of practices recommendations. The phosphorus is applied as per the treatments. Three levels of sodium as sodium chloride are also applied. Plant protection measures are taken as recommended in the package of practices of Kerala Agricultural University for Banana Nendran variety. Cowdung at the rate of 10 kg per plant is also applied one month after planting.

From preliminary observations moisture content at 1/3 atmosphere, is determined. It is calculated as 7.34 per cent. 20 per cent and 40 per cent depletion from this field capacity moisture content (7.34 per cent), are determined. Based on this irrigation scheduling are done once in two days and once in four days to supply the required water as per treatments.

3.3.3. Installation of tensiometers and soil thermometers

Manometric type tensiometers are fabricated in the laboratory and installed in the plots, with the cups buried at a depth of 15 cm from soil surface. Soil thermometers are also installed at a depth of 15 cm in plots to note the soil temperature. Weeding is done frequently and bunds are taken for each treatment.

3.4. Observations

Observations on biometric parameters, physico-chemical properties and mycorrhizal percentage are recorded.

3.4.1. Biometric observations

For three different seasons biometric observations are recorded. The biometric observations include:-

3.4.1.1. Height of the plant

From the base to the tip of pseudostem height is taken and are recorded in centimeters.

3.4.1.2. Number of leaves

Number of fully opened photosynthetically active leaves are noted.

3.4.1.3. Girth

Girth at the base of the pseudostem is taken.

3.4.1.4. Length of the leaf

It is taken from the tip of the lamina to the basal end of lamina.

3.4.1.5. Width of the leaf

Maximum width at the middle of the lamina are determined.

3.4.1.6. Leaf Area Index

Leaf area determined by the formula

LA = Length x Breadth x .8 (Murray, 1960)

It is expressed in cm^2 $plant^{-1}$

$$\text{Leaf Area Index} = \frac{\text{Total leaf area per plant}}{\text{Land area occupied by the plant}}$$

([illegible])

3.4.2. Mycorrhizal infection

Roots collected from three plants are pooled and these roots are processed for Vesicular - Arbuscular mycorrhizal root infection.

Staining of root samples of VA mycorrhiza and taking VAM Counts

The method of Philips and Hayman (1970) is used for observing VA mycorrhizal infection, in various root samples. One hundred root bits of approximately one centimeter length are examined, segment wise, for this purpose. The root bits are initially washed in tap water and softened by simmering in 10 per cent potassium hydroxide at 90°C for one hour. After cooling, the excess of alkali is removed by repeated rinsing in tap water and then acidified with two per cent hydrochloric acid before staining with 0.05 per cent trypan blue in lactophenol at 90°C for three minutes.

Preparation of trypan blue

Mix 50 mg Trypan blue (Romali) with 100 ml Lactophenol.

Preparation of lactophenol

Mix 10 ml Lactic acid, 10 ml phenol, 20 ml Glycerol and 20 ml water.

The excess stain from the root tissue is removed by clearing overnight in fresh lactophenol. Ten root bits are examined at a time for the typical VA - mycorrhizal infection under a light microscope. Each root bit is divided into four equal segements for recording the presence or absence of VA mycorrhiza and based on this different grades from 0 to 4 are given depending on the extent of mycorrhizal infection. The average value thus obtained for 100 root bits examined are taken as the mycorrhizal index.

3.4.3. Physical properties of soil

The soil samples collected for different seasons are analysed for the following physical properties.

3.4.3.1. Soil water status

Gravimetric soil water contents are recorded by collecting soil samples from 15 cm depths, for every season under study.

3.4.3.2. Soil temperature

Soil temperatures at 15 cm depth are recorded at 07.30 and 14.30 hours once in a week.

3.4.3.3. Textural analysis

Mechanical analysis is done by Bouyoucos hydrometer method. (Gupta and Dhakshinamoorthi, 1980).

3.4.3.4. Physical constants

Bulk density, particle density, water holding capacity volume of expansion and porosity for undisturbed soil samples are determined for all the seasons as described by Gupta and Dhakshinamoorthi (1980). The cores used are of length 8 cm and diameter 5 cm.

3.4.3.5. Aggregate analysis

Aggregate analysis is carried out by Yoder's wet sciving method (Yoder 1937) as described by Gupta and Dhakshinamoorthy (1980). The samples are wetted slowly and using a et of sieves, water stabble agoregates are determined. Mean weight diameter is used as structural index (Van Bavel (1949).

3.4.3.6. Hydraulic conductivity

Using the Jodpur constant head permeometer, hydraulic conductivity for samples from each treatment is determined (Gupta and Dhakshinamoorthy, 1980). Core samples are equilibrated with water overnight, and constant head is maintained using the permeameter. Quantity of water collected for 10 minutes are noted until concurrent values ob ained. Hydraulic conductivity 'k' was calculated using the Darcy's equation.

$$K = \frac{QL}{DHAt}$$

Where

K = hydraulic conductivity ($cmhr^{-1}$)

t = time in hour

Q = Amount of water collected in time 't' ($-cm^{-3}$)

L = Length of the soil column (cm)

A = Area of cross section of core (Cm^2)

H = Effective hydraulic head (Height from base of soil column to the top of the water level (-cm).

The maximum and minimum atmospheric temperatures are also recorded from the register maintained by the college observatory.

3.4.4. Chemical analysis

Chemical analysis are done for all the soil samples as given below.

3.4.4.1. Organic carbon is determined by Walkley and Black's rapid titration method (Jackson, 1973).

3.4.4.2. Available nitrogen is estimated using the permanganate titration method by Subbiah and Asija (1956).

3.4.4.3. Available phosphorus is estimated by Dickman and Bray's Molybdenum Blue Method (Jackson, 1973).

3.4.4.4. Exchangeable K, Ca, Mg and Na are estimated using Atomic Absorption Spectro photometer, Model-PE-3030 using ammonium acetate extract (Jackson, 1973).

3.4.4.5. Plant nitrogen is estimated by micro-kjeldhal's method using sulphuric acid extract (Piper, 1966).

3.4.4.6. Phosphorus in the plant sample is estimated by Vanadomolybdo phosphoric yellow colour method (Piper, 1966).

3.4.4.7. Potassium, Calcium, Magnesium and Sodium for plant samples are estimated using Atomic Absorption Spectrophotometer PE-3030, from triple acid extract.

3.4.5. Statistical analysis

The data obtained under various observations are statistically analysed as RBD and the results are interpreted.

RESULTS AND DISCUSSION

RESULT AND DISCUSSION

A field experiment is conducted using randomised block design with three replications in the Vellayani farm area. The observations for various parameters are statistically analysed and the results are presented in table No. 1 to 43 and figures 1 to 20.

The results obtained and the pertaining discussion, using the mean tables under the relevant titles are included in this chapter. The analysis of variance done for all the parameters are given in the appendix.

4.1. Biometric observations

Biometric observations such as height of the plant, number of leaves, girth of the pseudostem and leaf area index recorded during 90 and 180 days after planting and at the yielding stage (270 days D.A.P) are given in table 2 to 9.

4.1.1. Height of the plant

From tables 2 and 3 it can be seen that plant height values are not influenced by individual effects from phosphorus, sodium and water.

For the first and second stage for different levels of water and phosphorus, W_2P_0(74.67) has significant effect on plant height than W_2P_1 (55.44).

Table-2 <u>Effect of different levels of P, Na, water and their interactions on plant height</u>

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	64.56	63.22	60.11	96.67	109.63	105.00	237.78	249.67	259.00
W2	74.67	55.44	63.44	113.00	86.33	104.00	247.44	227.00	252.22
Na0	66.00	52.00	65.83	104.50	86.33	110.50	252.33	248.83	254.17
Na1	67.00	64.33	57.67	102.50	113.67	97.67	225.83	237.50	254.33
Na2	75.83	61.66	61.83	107.50	94.008	105.33	249.67	228.67	258.33
Mean for Phosphorus	69.62	59.39	61.78	104.84	98.00	104.50	242.61	238.34	255.61
CD at 5% level for P	-	9.66	-	-	11.02	-	-	14.7960	-
CD at 5% level for WxP	-	13.66	-	-	15.59	-	-	20.92	-
CD at 5% level for PxNa	-	16.73	-	-	19.09	-	-	25.63	-

Table-3 <u>Effect of different levels of Na, W and their interactions on plant height</u>

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	62.33	60.33	65.22	107.22	103.44	100.67	252.67	244.33	249.44
W2	60.22	65.67	67.67	93.67	105.78	103.89	250.89	234.11	241.67
Mean for Sodium	61.28	63.00	66.44	100.44	104.61	102.00	251.78	239.22	245.56
Mean for Water W1	-	62.63	-	-	103.78	-	-	248.81	-
Water W2	-	64.52	-	-	101.11	-	-	242.22	-
CD at 5% level for Water	-	7.89	-	-	8.99	-	-	12.08	-
CD at 5% level for Sodium	-	9.66	-	-	11.02	-	-	14.80	-
CD at 5% level for WxNa	-	13.66	-	-	15.59	-	-	20.92	-

From the plant height observed, during the yielding stage maximum value obtained for W_1P_2 (259.00 cm) which is significant over W_1P_3 (237.78 cm) and W_2P_1 (227.00). As seen from the result maximum plant height observed at highest level of water and highest level of phosphorus. Yawney *et al.*, (1982) also observed a decreased seedling growth by decreasing soil phosphorus for different pH ranges. Ali and Varade (1981) also have the opinion that emergence of rice seedlings in a clay soil decreased significantly with reduction in soil moisture content.

For all the stages, interaction of water and sodium has not influenced plant height. But for different levels of sodium and phosphorus, Na_2P_3 (75.63 cm) Na_1P_1 (113.57) and Na_2P_2 (250.33) combination influenced plant height for the three stages respectively.

With no sodium the effect of phosphorus on plant height is not prominent in all the stages. Though the phosphorus alone can influence plant height, in the presence of sodium, its effect can be enhanced to some extent. This is also agreeing with the work of Walker *et al.* (1987) that sodium accumulated from sodium chloride applied, in the shoots of *Pistacia vera* and *P. atlantica* were diluted by growth. These plants had a higher relative growth rate and a higher shoot to root ratio.

4.1.2. <u>Number of leaves</u>

Tables 4 and 5 give the mean values for number of leaves recorded during the three stages.

Individual effects of different levels of water, phosphorus and sodium are insignificant on number of leaves, at all the three stages.

In the case of combination of water and phosphorus W_1P_1 increases number of leaves in the first and second stages and it is significant over W_1P_0 in both stages. In the third stage W_2P_2 (5.33) is significant over W_2P_1 (3.56) and W_1P_1 (3.89). W_1P_0 is also on par with W_2P_2.

In the beginning of plant growth more water is required since the leaf development mainly confined to this stage. When the plant is matured, even at lower water levels, number of leaves have increased at higher levels of phosphorus.

The different levels of sodium and water combination have not increased the number of leaves, significantly during the plant growth. During the initial stages of plant growth combination of sodium at the rate of 68 g/plant/annum and phosphorus at the rate of 90 g/plant/annum has given significant value for number of leaves (10.17) which is higher than the values for all the other treatments. After 270 days of planting Na_2P_2 gives maximum value (5.33) which is significant, over Na_0P_0 (3.83) and Na_2P_1 (3.17). For

Table-4 Effect of different levels of P, Na, Water and their interactions on number of leaves

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	8.78	10.00	9.33	8.11	9.22	9.11	4.78	3.89	4.56
W2	9.44	7.67	9.56	9.00	8.00	9.22	3.78	3.56	5.33
Na0	8.83	8.33	10.00	8.83	8.83	9.17	3.83	4.17	5.00
Na1	8.83	10.17	9.00	7.83	9.50	9.50	4.67	3.83	4.50
Na2	9.67	8.00	9.33	9.00	8.00	8.83	4.33	3.17	5.33
Mean P	9.11	8.83	9.44	8.56	8.61	9.17	4.28	3.72	4.94
CD at 5% level for Phosphorus	-	0.8299	-	-	0.6426	-	-	0.8469	-
CD at 5% level for WxP	-	1.1740	-	-	0.9088	-	-	1.1977	-
CD at 5% level for P x Na	-	1.4370	-	-	1.1130	-	-	1.4669	-

Table-5 Effect of different levels of Na, W and their interactions on number of leaves

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	9.33	9.56	9.22	8.89	8.78	8.78	4.44	4.44	4.33
W2	8.78	9.11	8.78	8.67	9.11	8.44	4.22	4.22	4.22
Mean for Na0	9.06	9.33	9.00	8.78	8.94	8.61	4.33	4.33	4.28
Mean for W1	-	9.37	-	-	8.8148	-	-	4.4374	-
Water W2	-	8.89	-	-	8.7407	-	-	4.2220	-
CD at 5% level for water	-	0.6776	-	-	0.5247	-	-	0.6915	-
CD at 5% level for sodium	-	0.8299	-	-	0.6426	-	-	0.8469	-
CD at 5% level for WxNa	-	1.1740	-	-	0.9088	-	-	1.1977	-

Na_0P_2 (5.00) the number of leaves are almost equal to Na_2P_2. From the table it is observed that the sodium has no much influence on number of leaves. When phosphorus level increased to P_2 even with no sodium (Na_0) the number of leaves is found to be 5.00 at the later stages. Plant demand for phosphorus is also more during this stage. From the present study, the observations show that sodium does not have much influence on the number of leaves of the plant.

Annamma George (1980) has reported that during the initial stages of growth ie up to 60 days the phosphorus application had not influenced either plant height or number of leaves in the case of cowpea. The present result shows a response to phosphorus upto the P_2 level but there is no significant increase in growth factors for higher level of phosphorus along higher sodium. It shows that phosphorus is required for the proper foliage during plant growth in case of banana.

4.1.3. Girth of the pseudostem of banana plant

Girth of the plant measured at the lower most position of the pseudostem for all the treatments and circumferance obtained are recorded and mean values are given in table No. 6 to 7.

There is no significant effect on the girth of the stem for different water, phosphorus and sodium levels excepting

Table-6 <u>Effect of different levels of P, Na, Water and their interactions on the girth</u>

(in cms)

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	23.61	27.94	26.39	49.00	50.44	52.11	49.33	52.67	53.89
W2	28.61	23.00	26.00	50.78	106.22	50.89	52.33	45.67	51.22
Na0	25.50	21.75	29.33	51.00	51.17	50.00	53.83	51.67	52.67
Na1	25.50	29.33	23.58	47.67	52.00	53.00	47.00	53.17	52.00
Na2	27.33	25.33	25.67	51.00	131.83	51.50	51.67	42.67	52.50
Mean for Phosphorus	26.11	25.47	26.20	49.89	78.33	51.50	50.83	49.17	52.56
CD at 5% level for Phosphorus	-	2.45	-	-	-	46.38	-	3.1149	-
CD at 5% level for WxP	-	3.47	-	-	-	65.60	-	4.41	-
CD at 5% level for PxNa	-	4.25	-	-	-	80.34	-	5.40	-

Table-7 <u>Effect of different levels of Na, W and their interactions on the girth</u>

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	27.00	25.28	25.67	51.11	50.78	49.67	54.11	50.67	51.11
W2	24.06	27.00	26.56	50.33	51.00	106.56	51.33	51.11	46.78
Mean for Sodium	25.53	26.14	26.11	50.72	50.89	78.11	52.72	50.89	48.94
Mean for Water W1	-	25.98	-	-	50.52	-	-	51.96	-
Mean for Water W2	-	25.87	-	-	69.29	-	-	49.74	-
CD at 5% level for Water	-	2.00	-	-	37.87	-	-	2.54	-
CD at 5% level for Sodium	-	2.45	-	-	46.38	-	-	3.11	-
CD at 5% level for WxNa	-	3.47	-	-	65.60	-	-	4.41	-

the control treatment of sodium which gives a value of 52.72 significantly differing from second level of sodium in the yielding stage of the plant.

The dimensions of the girth of the plant shows a decreasing tendancy at lower phosphorus levels with lower water content. W_2P_1 is inferior to other treatments in both first and third stages. This treatment gives a mean value of 45.67 which is the least value. Highest water level along with highest phosphorus level W_1P_2 shows the maximum value of 53.89. For the optimum growth of the girth, water and phosphorus cannot be limited to the lowest levels.

The effect of water on growth characters is also stressed by Ahlawat et al., (1978). For cowpea in a field experiment, he found, that by increasing the soil moisture from 25 to 50 per cent of available soil moisture at 0-30 cm, depth, the plant height and other characters increased to a favourable growth rate.

For the first and second stage sodium is not affecting girth of the stem. But when the plant reached yielding stage, at higher levels of sodium and lower level of water the size of girth decrease.

For different levels of sodium and phosphorus highest value of girth is obtained, when sodium and phosphorus are applied as medium level (Na_1P_1) giving values of 29.33 and 53.17 for the first and third stage. For increasing girth size sodium is required only in minimum amount at higher levels of phosphorus.

When more water is applied to the soil, probably the increased uptake of water by the stem would have caused the higher diamensions of girth of the pseudostem at higher water levels.

4.1.4. Leaf area index

Leaf area index calculated for three stages of growth are given in table 8 and 9 and Fig. 2. Three levels of sodium and phosphorus and two levels of water are not affected LAI throughout the plant growth.

LAI shows a decreasing tendancy at lower water levels with phosphorus at 90 g/plant/annum. Highest value of LAI noted for W_1P_1 in the initial stages (.6142, .8871) but a maximum value of 1.081 is recorded for W_2P_2 in the later stages.

Interaction of sodium and water has not influenced leaf area index in any of the stages. In the initial stages either sodium or phosphorus at higher levels (Na_0P_2 and Na_2P_0) give higher values of leaf area index (0.88 and 0.87) which is on par with Na_1P_1 (.89). But during the later stage combination

Table-8 Effect of P, Na, Water and their interactions on LAI

P	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	.3790	.6142	.3610	.6602	.8871	.8109	.8586	.8609	0.9640
W2	.5091	.2957	.4471	.8726	.5418	.7797	.6194	.6993	1.0809
Na0	.3971	.5560	.4460	.7599	.5999	.8780	.7307	.8436	1.0057
Na1	.4466	.4571	.3671	.6713	.8997	.7691	.8200	.8350	0.9666
Na2	.4886	.3517	.3989	.8680	.6438	.7388	.6663	.6617	1.0949
Mean for Phosphorus	.4441	.4550	.4041	.7664	.7145	.7953	.7390	.7801	1.0224
CD at 5% level for Phosphorus	-	.2064	-	-	.1562	-	-	.2113	-
CD at 5% level for WxP	-	.2919	-	-	.2209	-	-	.2989	-
CD at 5% level for PxNa	-	.3575	-	-	.2706	-	-	.3660	-

Table-9 Effect of different levels of Na, W and their interactions on LAI

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	.5835	.3983	.3723	.8278	.7600	.7704	.9556	.9287	.7992
W2	.3492	.4490	.4538	.6641	.800	.7300	.7645	.8190	.8160
Mean for Sodium	.4664	.4236	.4131	.7459	.7800	.7502	.8600	.8739	.8076
Mean for Water W1	-	.4514	-	-	.7861	-	-	.8945	-
Mean for Water W2	-	.4173	-	-	.7314	-	-	.7999	-
CD at 5% level for water	-	.1685	-	-	.1276	-	-	.1726	-
CD at 5% level for Sodium	-	.2064	-	-	.1562	-	-	.2113	-
CD at 5% level for WxNa	-	.2919	-	-	.2209	-	-	.2989	-

Fig.2. Effect of different levels of Na, P, Water and their interaction on LAI during II and III stage.

Fig. 3. Effect of different levels of Na, P, Water and their interaction on mycorrhizal percentage during second and third stage.

Fig.2

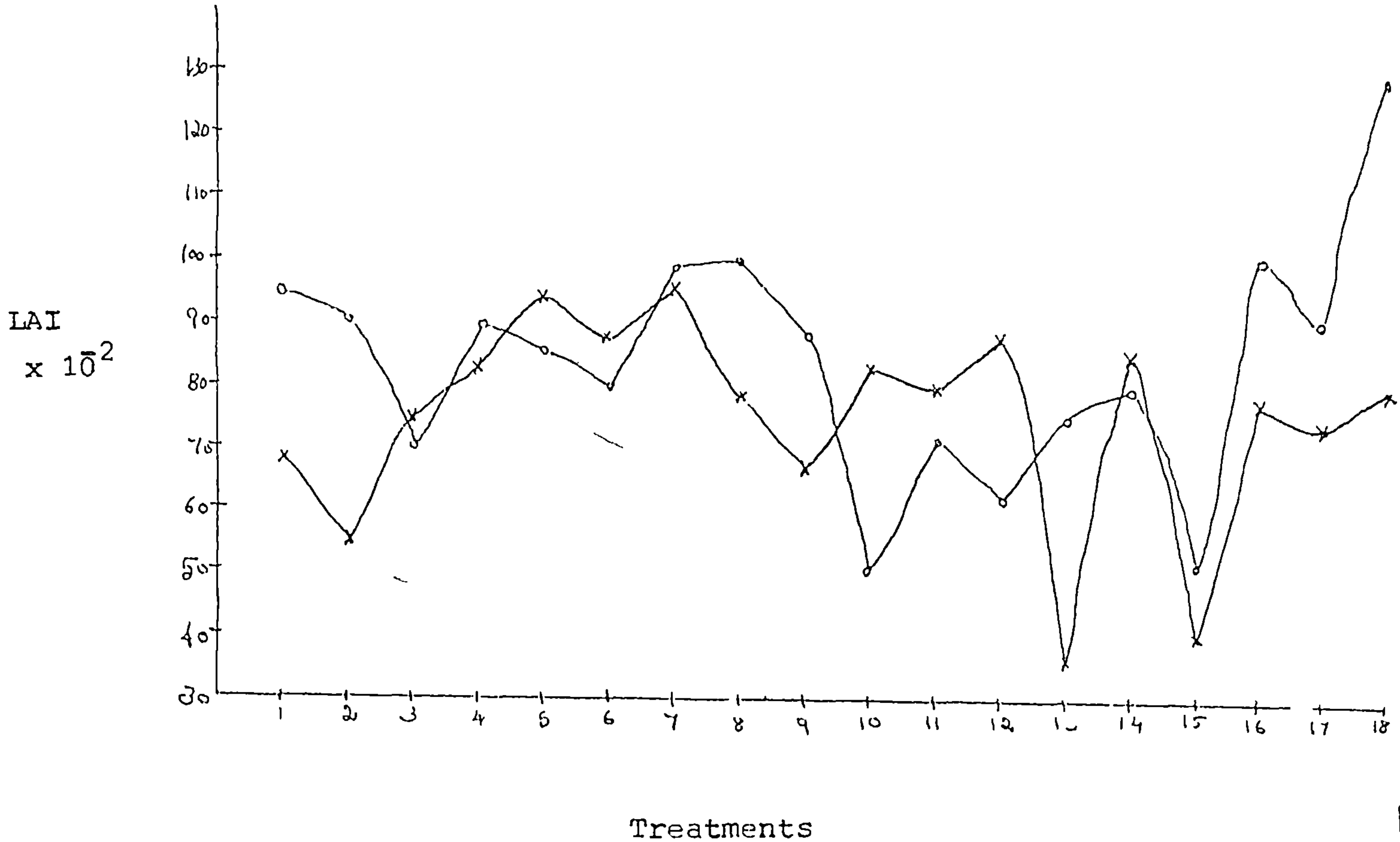
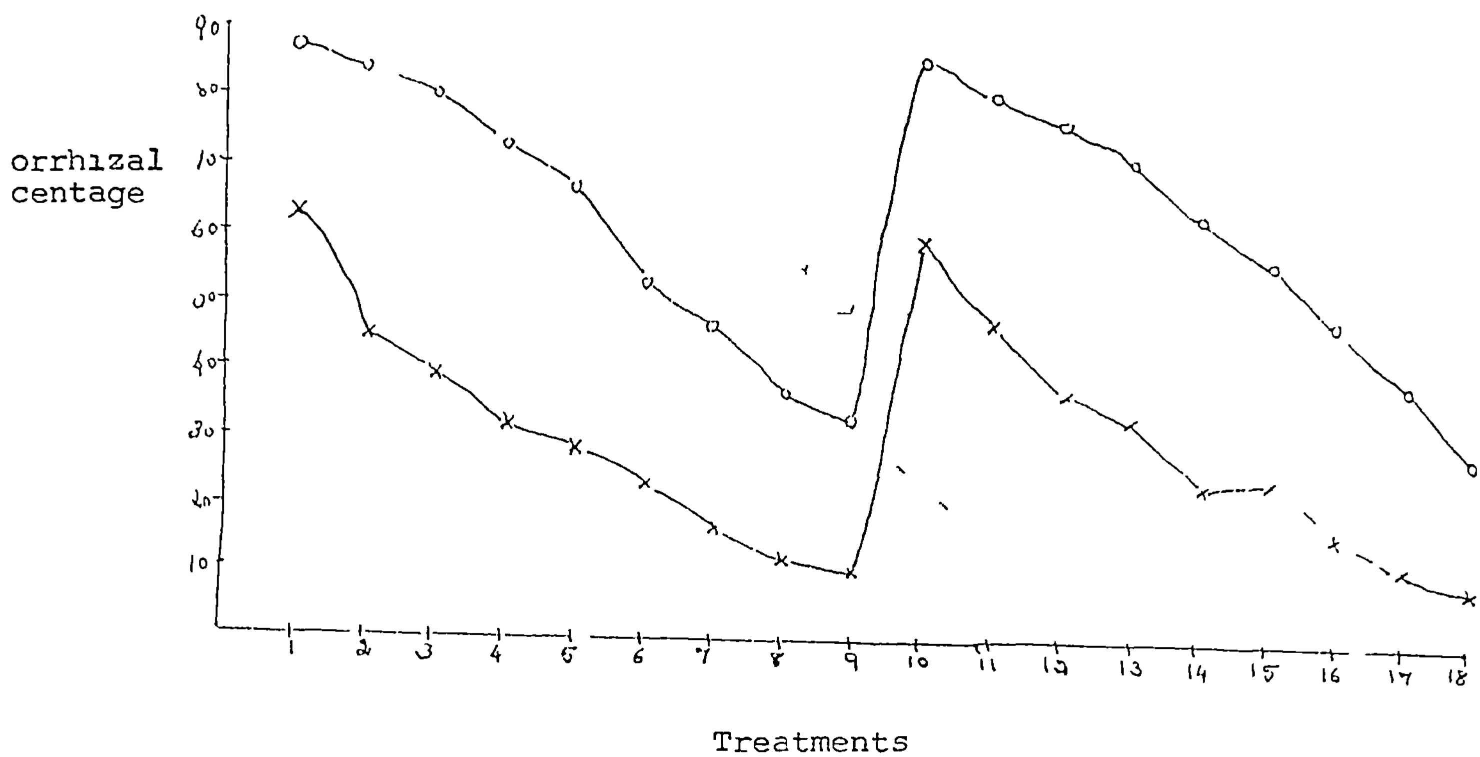


Fig.3



of maximum phosphorus and sodium (Na_2P_2) gives a maximum value for leaf area index 1.09, which is superior over Na_2P_1, Na_2P_0 and Na_0P_0.

Early stages of plant growth requires a higher water level W1 and lower phosphorus level as per the leaf area index is concerned. But when the plant grows, even at lower water levels (W2) in the presence high levels of phosphorus leaf area index is found to show increased value. When the yield factors are taken into consideration lower levels of sodium or phosphorus are sufficient at later stages, since photosynthetic activity are reduced during this stage. Plant height and leaf area index of greengram was significantly increased by application of phosphorus, when it is gradually increased from zero to 50 kg P_2O_5 ha^{-1}. This observation by Rollin Bhaskar (1979) is in agreement with the present result obtained.

4.2. Mycorrhizal infection

Mycorrhizal infection is found to be influenced by various soil, plant and atmospheric parameters. Correlation has been worked out with soil moisture percentage, water holding capacity, hydraulic conductivity, mean weight diameter, soil phosphorus, soil sodium, plant phosphorus and plant sodium. Correlation matrix is given for interpretation in table No. 43 to 45 and Fig. 3.

Effect of different levels of Na, P, Water and their interactions on mycorrhizal infection in Banana root

Table-10 Mean table for mycorrhizal percentage

No.	Treatments	I stage	II stage	III stage
1.	W2 P0 Na0	56.00	63.00	87.75
2.	W2 P0 Na1	40.00	45.00	84.25
3.	W2 P0 Na2	38.00	39.25	80.00
4.	W2 P1 Na0	49.00	32.00	73.50
5.	W2 P1 Na1	20.00	28.50	67.00
6.	W2 P1 Na2	17.00	23.25	52.25
7.	W2 P2 Na0	25.00	15.50	46.25
8.	W2 P2 Na1	18.00	12.00	36.50
9.	W2 P2 Na2	11.00	10.75	32.00
10.	W1 P0 Na0	52.00	59.50	85.75
11.	W1 P0 Na1	41.00	47.75	80.50
12.	W1 P0 Na2	39.00	37.40	76.25
13.	W1 P1 Na0	33.00	33.00	71.25
14.	W1 P1 Na1	34.00	23.25	62.00
15.	W1 P1 Na2	31.00	24.50	56.75
16.	W1 P2 Na0	27.00	16.00	46.50
17.	W1 P2 Na1	16.00	12.25	38.00
18.	W1 P2 Na2	12.00	8.50	28.25
Mean value for				
	P0	44.33	48.65	82.42
	P1	30.67	27.42	63.79
	P2	18.17	12.50	37.92
	Na0	40.33	36.50	68.50
	Na1	28.17	28.13	61.38
	Na2	24.67	23.94	54.25
	W1	30.44	29.92	60.58
	W2	31.67	29.13	62.58

The average atmospheric temperature, rainfall and relative humidity for the three seasons are calculated for interpretation of mycorrhizal infection. Seasonal effects are mainly due to these three factors. No seperate analysis have been done with these three atmospheric factors. The mean values obtained for mycorrhizal percentage is given in table No.10 and weather factors in table No. 10(a).

In all the three stages maximum mycorrhizal infection is observed for P_0Na_0 (56, 63 and 87.75) irrespective of water levels. With increase in sodium level there is a decrease in the mycorrhizal percentage (Correlation table No. 43 and 45). Within the same sodium level with increase in phosphorus there is a decrease in mycorrhizal count. Since water treatment is given only in the third stage, effect of it is observed only in the third stage.

As the phosphorus level increased mycorrhizal percentage decreased. During the third season where the actual water treatments are given the mycorrhizal percentage is found higher in the lower water level.

The observations shows that sodium and phosphorus at the minimum level is sufficient for proper growth of mycorrhiza which is the consonance with the results of Islam et al., (1980). They found that the phosphate application reduced

Table-10(a) Mean temperature, rainfall and relative humidity at the three growth stages of banana plant

		90 DAP*	180 DAP	270 DAP
Atmospheric Temperature (°C)	Maximum	32.77	30.43	32.82
	Minimum	24.57	23.50	22.98
Rainfall (mm)		52.13	205.03	84.36
Relative humidity (%)		71.33	79.00	67.60

*DAP = Days after planting

the degree of infection of mycorrhizal fungi without affecting plant growth in the field. Peter et al., (1986) have also reported that the processed water from shale industry containing increased concentration of calcium, magnesium, sodium, nitrate and ammonium as well as with high electrical conductivity if applied to the crops, result in reduced mycorrhizal activity in treated soils.

Water treatment are not given during the first and second season. But during the third season when water level is kept as a limiting factor there also mycorrhizal counting shows no much difference between the two levels of water. Maximum mycorrhizal infection is recorded during the third season for all the treatments than the first and second season. The data for relative humidity, rainfall and atmospheric temperature for the three seasons shows a maximum average rainfall and relative humidity during second season and optimum during the third season (R.H. 67.6, rainfall 84.36 cm). Optimum values of temperature, relative humidity and rainfall during the third season would have favoured the mycorrhizal population to some extent.

When soil phosphorus and soil moisture are correlated with mycorrhiza a positive correlation is obtained for the first season while during second and third season a negative correlation is obtained (Correlation table No.43). When mean weight diameter, soil sodium and water holding capacity are concerned *r* - value for correlation with mycorrhizal population is very small. There is a positive correlation existing between plant phosphorus plant sodium with mycorrhizal population having a percentage of 45 and 13. (Table - 45). Dakessian *et al*., (1986) obtained the result that soil water status and the mycorrhizal conditions interact in influencing plant growth which is agreeing with the result of this experiment. Hydraulic conductivity is negatively correlated with mycorrhizal population. As per an early report ~~by [illegible]~~, in case of hydraulic conductivity the microbial sealing in the soil causes a reduction in hydraulic conductivity. Such that when the mycorrhizal infection increased it might have reduced the hydraulic conductivity as shown by correlation studies.

4.3. Physical properties of soil

In the present study soil physical parameters are very important, since soil moisture characters, structural factors and porosity are interrelated with the biological and chemical properties like mycorrhizal spopulation, soil sodium and soil phosphorus. Mean table for all the physical parameters exceptingmean weight diameter and hydraulic conductivity after analysis of variance are given in table 11 to 23 and with relevant figures 4 to 11.

4.3.1. Soil moisture

Soil moisture percentage at a depth of 15 cm at the three stages of plant growth are determined and presented in table 11 and 12 and Fig. 4.

Different levels of sodium, phosphorus and water as such are not influenced soil moisture per cent for the three stages studied. But in the third stage sodium at the rate of 68 g/plant/annum has increased moisture percentage to 6.87 from 5.22 for no sodium treatment. In the initial stages even with no phosphorus, moisture percentage found to be highest (23.77) at lower water content. When the plant started growing there is no significant interaction effect of water and phosphorus on moisture percentage. When the sodium level increased from Na_0 to Na_1 at higher water content moisture percentage is 7.85, which is significant over W_1Na_0 (4.65), W_1Na_2 (5.28) and W_2Na_1 (5.78). There is no significant effect for the interactions of sodium and water, and phosphorus and sodium during initial stages.

Highest value of moisture percentage for treatment Na_1P_0 (7.86) which is significant over Na_0P_0 (5.01), Na_2P_0 (5.09) and Na_0P_1 (5.09). The results shows that plots received sodium at a rate of 68 g/plant/annum can retain

Table-11 Effect of different levels of P, Na, Water and their interaction on soil moisture per cent

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	18.67	20.89	17.55	6.76	6.02	6.34	6.63	4.67	6.47
W2	23.77	17.01	17.55	5.88	6.02	6.33	5.34	6.50	6.20
Na0	23.83	15.16	19.77	6.20	5.92	5.73	5.02	5.09	5.56
Na1	21.66	18.42	14.44	6.20	6.69	6.68	7.86	5.53	7.23
Na2	18.18	23.29	18.45	6.57	6.02	6.58	5.09	6.13	6.22
Mean for P	21.22	18.95	17.55	6.32	6.22	6.33	5.99	5.58	6.34
CD at 5% level for P	-	4.7700	-	-	0.8488	-	-	1.5303	-
CD at 5% level for PxW	-	6.7493	-	-	1.2004	-	-	2.1640	-
CD at 5% level for PxNa	-	8.2662	-	-	1.4700	-	-	2.6510	-

Table-12 Effect of different levels of Na, Water and their interactions on soil moisture per cent

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	17.07	17.48	22.56	5.95	6.65	6.51	4.66	7.83	5.28
W2	22.10	18.86	17.38	5.95	6.40	6.27	5.79	5.91	6.35
Mean for Na	19.58	18.17	19.97	5.95	6.53	6.39	5.22	6.87	5.82
Mean for Water W1	-	19.03	-	-	6.37	-	-	5.92	-
Mean for Water W2	-	19.44	-	-	6.21	-	-	6.01	-
CD for Water at 5% level	-	3.8968	-	-	0.6931	-	-	1.2495	-
CD for Na at 5% level	-	4.7725	-	-	0.8488	-	-	1.5303	-
CD at 5% level for WxNa	-	6.7493	-	-	1.2004	-	-	2.164	-

Fig. 4. Effect of different levels of Na, P, Water and their interaction on soil moisture percentage during third stage.

Fig. 5. Effect of different levels of Na, P, Water and their interaction on soil bulk density during 3rd stage.

Fig 4

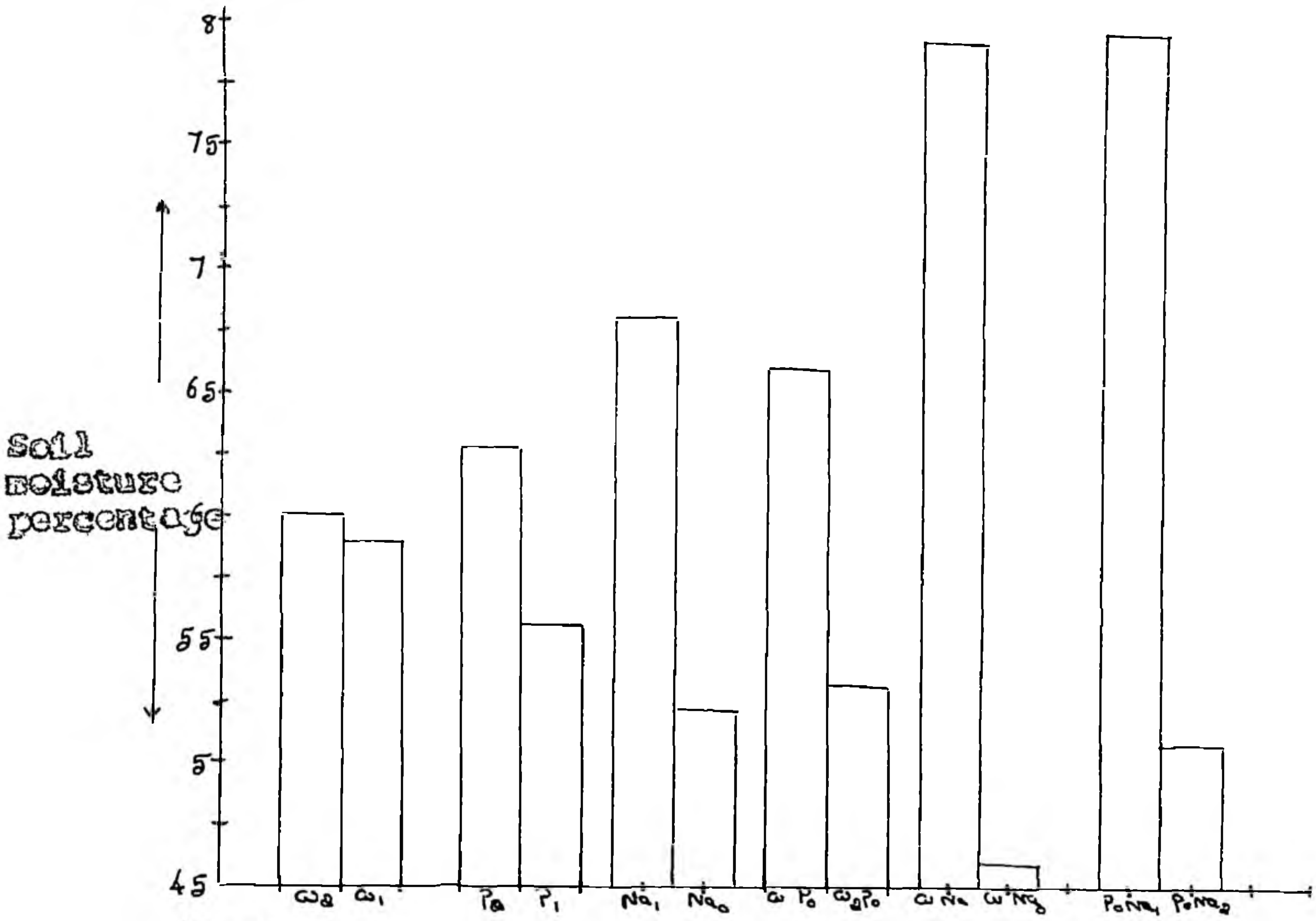
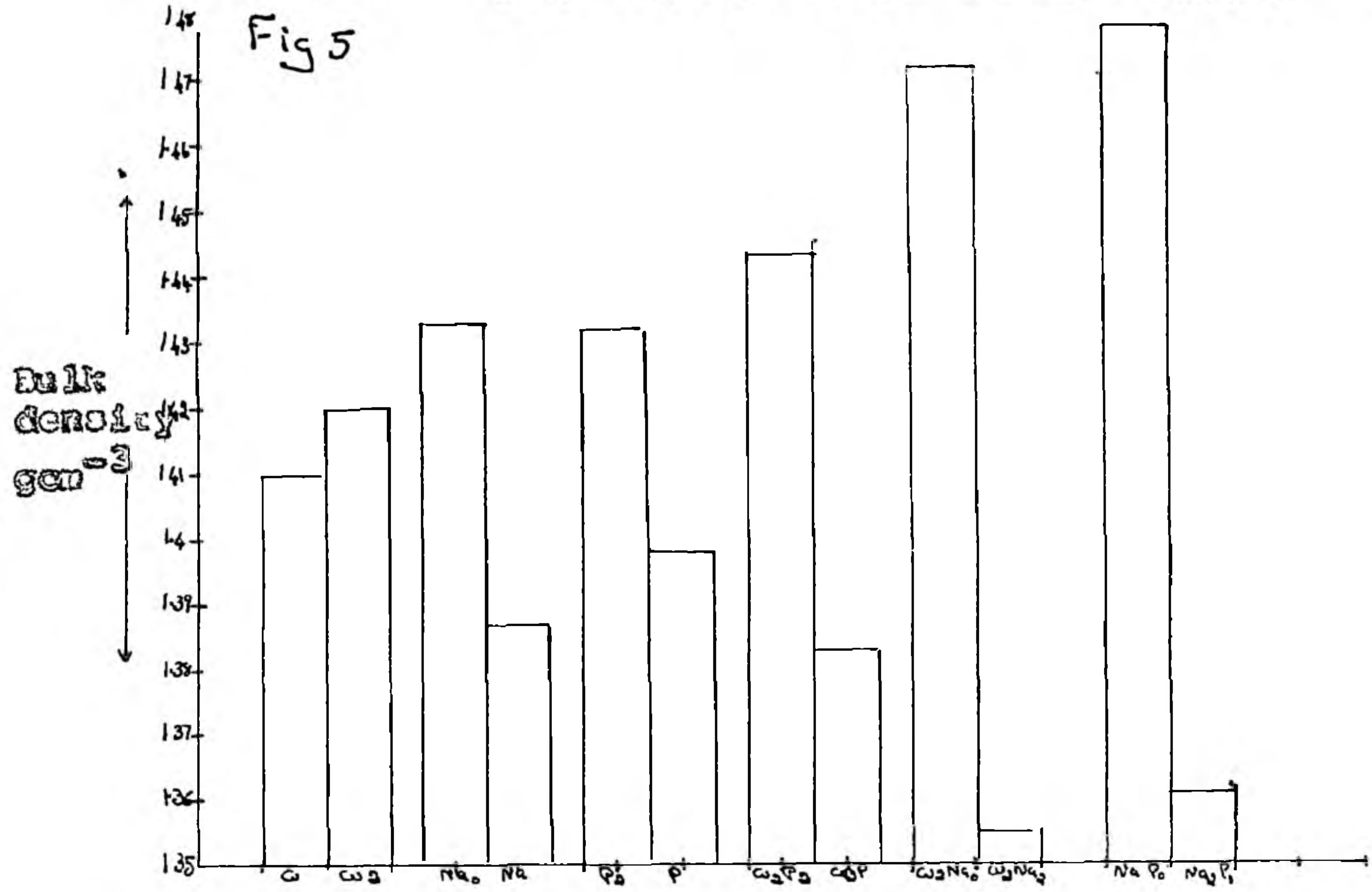

Soil moisture percentage
8
7.5
7
6.5
5.5
5
4.5

Fig 5


Bulk density gcm-3
1.48
1.47
1.46
1.45
1.44
1.43
1.42
1.41
1.4
1.39
1.38
1.37
1.36
1.35

soil moisture than the plots which received no sodium or sodium at the rate of 136 g/plant/annum. Increase in phosphorus level is not found to have any influence on moisture content. Sodium in the exchange complex might have helped the water adsorption and increase the moisture content. This result is in agreement with the findings of Acharya and Abrol (1977) that in the drying pattern of soil, the first stages of drying was delayed in low ESP treatments compared to high ESP treatments, because of regular movement of water from lower layers to the surface to meet evaporation demand. Higher sodium content in the soil can reduce the water movement. This result is in confirmity with the study of Pandey and Pathak (1975) that in the case of physical properties of normal and salt affected soils, high sodium saturation increase bulk density and decrease non capillary porosity, resulting in low hydraulic conductivity. But the medium dose of sodium helped soil aggregation and the water conductance is thereby increased.

4.3.2. <u>Bulk density and Particle density</u>

The bulk density and particle density calculated at 15 cm depth of the soil at the three stages and presented the mean value in tables 13 to 16 and in figures 5 and 6.

Bulk density and particle density for the first two stages are not affected by the two water levels. But in the

Table-13 Effect of different levels of P, Na, Water and their interactions on bulk density (in g cm^{-3})

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	1.2975	1.2200	1.2537	1.4113	1.3862	1.3609	1.3981	1.4133	1.4209
W2	1.2371	1.2357	1.2604	1.3805	1.3759	1.3991	1.4400	1.3830	1.4438
Na0	1.2478	1.2183	1.2593	1.3882	1.4103	1.3797	1.4075	1.4534	1.4391
Na1	1.2590	1.2399	1.2941	1.3953	1.3734	1.3691	1.4789	1.3798	1.4285
Na2	1.2952	1.2254	1.2178	1.4044	1.3593	1.3912	1.3708	1.3611	1.4295
Mean P	1.2673	1.2279	1.2571	1.3959	1.3811	1.3800	1.4191	1.3982	1.4324
CD at 5% for P	-	0.0651	-	-	0.0397	-	-	0.0367	-
CD at 5% level for PxW	-	0.0921	-	-	0.0561	-	-	0.0519	-
CD at 5% level for PxNa	-	0.1128	-	-	0.0687	-	-	0.0636	-

Table-14 Effect of different levels of Na, W and their interactions on bulk density

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	1.2359	1.2664	1.2689	1.3950	1.3714	1.3917	1.3944	1.4186	1.4192
W2	1.2477	1.2622	1.2233	1.3902	1.3870	1.3783	1.4723	1.4394	1.3550
Mean for Na	1.2418	1.2643	1.2461	1.3927	1.3792	1.3850	1.4334	1.4290	1.3871
Mean for Water W1	-	1.2571	-	-	1.3861	-	-	1.4108	-
W2	-	1.2444	-	-	1.3852	-	-	1.4222	-
CD at 5% level for water	-	0.0532	-	-	0.0324	-	-	0.0290	-
CD at 5% level for Na	-	0.0651	-	-	0.0397	-	-	0.0367	-
CD for WxNa	-	0.0921	-	-	0.0561	-	-	0.0519	-

third stage lower water level reduce bulk density and particle density, where particle density is significantly different between two levels (2.27 and 2.34). Phosphorus application reduce bulk density and particle density. There is significant difference between P1 and P2 for bulk density values during the third stage. As the sodium level increased from Na_0 to Na_1 both bulk density and particle density reduce from 1.43 to 1.30 and 2.31 to 2.20 respectively.

Interaction effect of water and phosphorus and water and sodium has no significant effect on bulk density and particle density during the first stage of growth. Lowest value of particle density obtained for Na_2 P_2 (1.95). The treatment W_1 Na_1 and W1 P_2 gives lowest values of bulk density and particle density of 1.37 and 2.24 during the second stage of growth. Interaction effect of sodium and phosphorus over bulk density and particle density has no significance in the second stage.

During third stage P_1 W_2 gives lowest value of bulk density of 1.38 and P_2 W_1 gives the lowest value of particle density (2.25).

For both bulk density and particle density highest sodium level gives minimum value during the third stage. But particle density reduce with higher water level and bulk

Table-15 Effect of different levels of P, Na, Water and their interactions on particle density (in $g cm^{-3}$)

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	2.1377	2.0587	2.2004	2.3119	2.2880	2.2500	2.2795	2.2798	2.2475
W2	2.0921	2.2519	2.1159	2.2958	2.3480	2.3200	2.3089	2.4107	2.2850
Na0	2.0312	2.1003	2.1715	2.3210	2.3990	2.3110	2.2901	2.4230	2.2170
Na1	2.1238	2.1666	2.3530	2.2870	2.2990	2.2480	2.2850	2.5860	2.3050
Na2	2.1897	2.1990	1.9490	2.3037	2.2580	2.2940	2.3081	2.0270	2.2770
Mean P	2.1149	2.1553	2.1582	2.3039	2.3180	2.2850	2.2942	2.3453	2.2663
CD at 5% level for P	-	0.1598	-	-	0.0681	-	-	0.0796	-
CD at 5% level for WxP	-	0.2260	-	-	0.0964	-	-	0.1004	-
CD at 5% level for PxNa	-	0.2768	-	-	0.1181	-	-	0.1229	-

Table-16 Effect of different levels of Na, Water and their interactions on particle density

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	2.0631	2.1688	2.1649	2.2960	2.2420	2.3130	2.2587	2.3951	2.1531
W2	2.1388	2.2602	2.0608	2.391	2.3135	2.2568	2.361	2.3890	2.2550
Mean for Na	2.1010	2.2145	2.1128	2.3435	2.2779	2.2849	2.3100	2.3918	2.2041
Mean for W1	-	2.1323	-	-	2.2830	-	-	2.2690	-
Water W2	-	2.1533	-	-	2.3205	-	-	2.3350	-
CD for water at 5% level	-	0.1305	-	-	0.0556	-	-	0.0579	-
CD for Na at 5% level	-	0.1598	-	-	0.0683	-	-	0.0796	-
CD for WxNa at 5% level	-	0.2260	-	-	0.0964	-	-	0.1004	-

Fig. 6. Effect of different levels of Na, P, Water and their interaction on soil particle density during third stage.

Fig. 7. Effect of different levels of Na, P, Water and their interaction on water holding capacity during third stage.

Fig 6

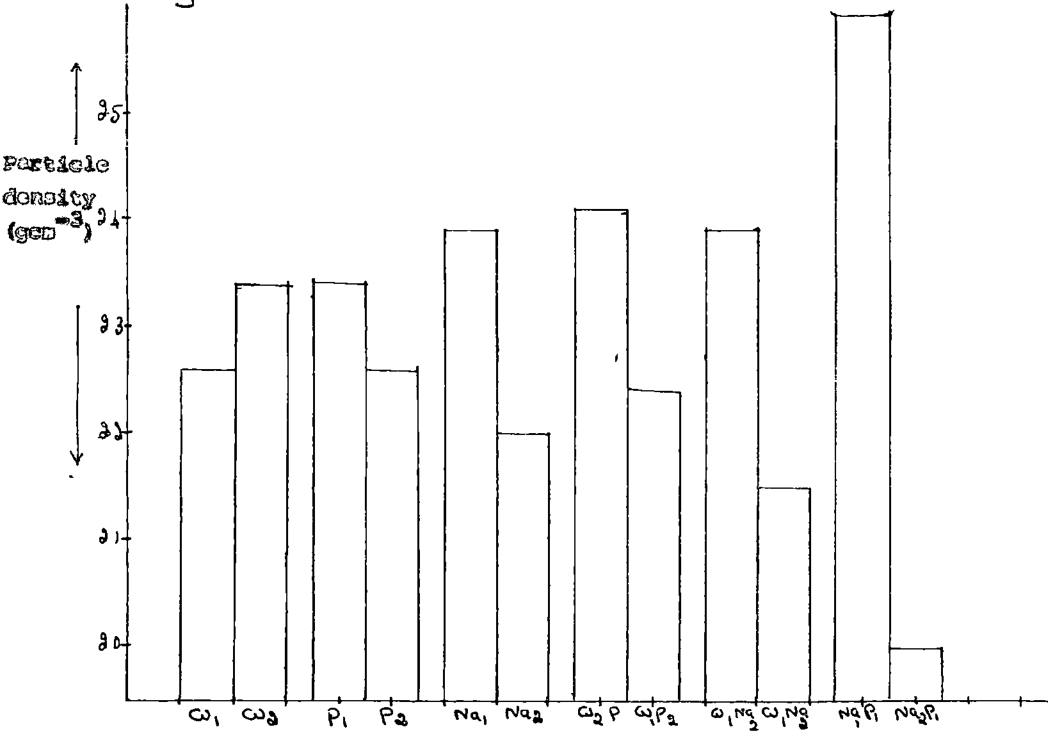
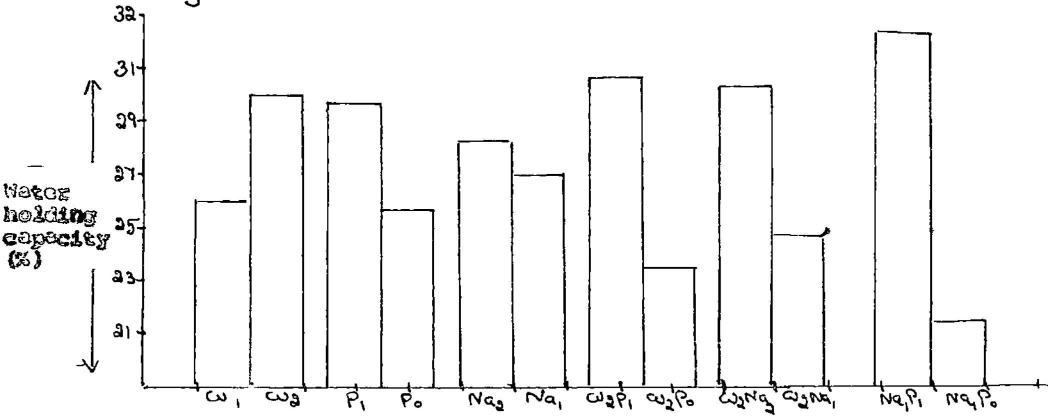

Particle density (gcm-3)
25
24
23
22
21
20
W1
W2
P1
P2
Na1
Na2
W2P
W1P2
W1Na2
W1Na2
Na1P1
Na2P1

Fig 7


Water holding capacity (%)
32
31
29
27
25
23
21
W1
W2
P1
Po
Na2
Na1
W2P1
W2Po
W2Na2
W2Na1
Na1P1
Na1Po

density reduce with lower water level Olliver *et al.*, (1986) also concluded from their investigations, the same result that bulk density increased with depth and decreased with increasing water content. The combination of sodium at the rate 136 g/plant/annum and phosphorus at the rate of 90 g/plant/annum reduce the bulk density to 1.36 and particle density to 2.02 which is significant over other treatment.

Without considering water levels the bulk density and particle density has been reduced to a favourable value in the presence of sodium and phosphorus. Sodium in the exchange complex increase aggregation and reduce soil compaction thereby reducing the bulk density and particle density.

4.3.3. Water holding capacity

The water holding capacity for all the samples collected at 15 cm depth at the three stages are calculated and mean values are given in table No. 17 and 18 and in Fig. 7.

Levels of water, phosphorus and sodium have not influenced the water holding capacity of soil in the first two stages. During the third stage higher level of water W_1 (28.3) and phosphorus at the rate of P_1 (29.85) individually increased water holding capacity of soil. Sodium has no effect on water holding capacity in any of the stages of the plant. For the first two seasons there is no interaction effect on water holding capacity by the combined treatment of water and phosphorus, Table-17 <u>Effect of different levels of P, Na, Water and their interactions on water holding capacity</u> (%)

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	32.17	38.42	36.59	28.37	29.03	30.58	28.23	29.11	27.54
W2	37.61	37.96	36.03	30.82	30.39	31.02	23.47	30.60	25.75
Na0	37.11	37.22	37.86	31.22	29.33	30.23	26.60	28.57	26.14
Na1	34.58	40.14	33.43	28.99	29.46	29.03	21.43	32.24	27.42
Na2	32.99	37.21	37.64	28.57	30.35	33.14	29.51	28.75	26.38
Mean P	34.89	38.19	36.31	29.60	29.71	30.80	25.85	29.85	26.65
CD at 5% level for Phosphorus	-	6.3960	-	-	3.1460	-	-	1.8439	-
CD at 5% level for WxP	-	9.0450	-	-	4.4499	-	-	2.6070	-
CD at 5% level for PxNa	-	11.078	-	-	5.449	-	-	3.1936	-

Table-18 <u>Effect of different levels of Na, Water and their interactions on water holding capacity</u> (%)

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	35.27	36.21	35.71	28.92	28.89	30.17	29.11	29.44	26.32
W2	39.53	35.89	36.18	31.59	29.43	31.20	25.09	24.63	30.10
Mean for Na	37.40	36.05	35.95	30.26	29.16	30.68	27.10	27.03	28.21
Mean for W1	-	35.71	-	-	29.33	-	-	28.29	-
Water W2	-	36.18	-	-	30.74	-	-	26.61	-
CD at 5% level for water	-	5.2200	-	-	2.5690	-	-	1.5060	-
CD at 5% level for Na	-	6.3960	-	-	3.1460	-	-	1.8439	-
CD at 5% level for WxNa	-	9.0450	-	-	4.4499	-	-	2.607	-

water and sodium, and sodium and phosphorus. With different levels of phosphorus and water highest level of water holding capacity is showed by W_2P_1 (30.60) followed by W_1P_1 (29.11). These two are significant over W_2P_0 (23.47) and W_2P_2 (25.75).

Lowest level of water and sodium give a lower value of water holding capacity (25.09). While sodium applied at the rate of 13C g/plant/annum, with lower level of water increased water holding capacity, to a value of 30.1 which is significant over W_1Na_2 (26.32) W_2Na_0 (25.09) and W_2Na_1 (24.63).

A water holding capacity of 33.24 is recorded for P_1Na_1 which is significant over all other treatments excepting Na_2P_0 (29.51) which is on par with P_1Na_1.

First two stages where water treatments are not given, there is no significant effect of water levels and levels of phosphorus. But treatment effects are apparantly shown during the third stage where soil received higher water levels, recorded higher water holding capacity. Generally when more water is present in the soil, there is increase in the water holding capacity of the soil especially in the heavy textured or loamy soil. Phosphorus at the medium level is recommendable for increasing water holding capacity than no phosphorus or higher levels of phosphorous. The view is supported by Adhikari et al. (1986) he showed that phosphate given together with organic matter increased the water holding capacity and reduced the plasticity. Interaction effects are also predominant only during the third stage were water treatments are effective.

As a general case application of phosphorus and sodium may increase water holding capacity. Higher level of water holding capacity at lower water levels might be due to presence of higher levels of sodium in the complex. Abrol et al. (1978) from his experiment came to the same conclusion that with increasing exchangeable sodium percentage (ESP) moisture retension increased at soil water suction greater than about 0.2 atm.

4.3.4. Volume of expansion

Using the core samples collected, volume of expansion for all soil samples at 15 cm depth are determined for all the three stages. The mean values are presented in table No. 19 and 20 and in Fig.8.

Sodium given at three levels and water at two levels do not change the volume of expansion values. For different levels of phosphorus during third stage highest value of volume of expansion was observed for the second dose of phosphorus (2.61) which is significant over control level of phosphorus (1.64).

For the first and second season W_1P_0 gives highest values (3.77, 1.30). But during the third stage maximum volume of expansion value of 2.38 is obtained for higher levels of phosphorus with higher levels of water. Lowest level of water and phosphorus gives the minimum value of 1.53. Interaction effect of sodium and water is not significant during plant growth. Though the treatment Na_1P_0 is found to be significant during the first stage of growth (3.38), in the later stages

Table-19 Effect of different levels of P, Na, Water and cheir interactions on volume of expansion (%)

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	3.77	2.01	1.97	1.30	2.60	2.02	1.72	2.52	2.88
W2	2.65	2.10	2.02	1.72	1.19	1.48	1.53	1.84	2.35
Na0	2.95	2.15	1.90	1.26	1.20	2.22	1.44	2.40	2.07
Na1	3.38	1.77	1.44	1.72	2.16	1.18	1.65	2.08	2.60
Na2	3.30	2.25	2.64	1.55	2.32	1.86	1.78	2.05	3.17
Mean P	3.21	2.06	1.99	1.51	1.89	1.75	1.63	2.05	3.17
CD at 5% level for P	-	1.0525	-	-	0.8539	-	-	0.8420	-
CD at 5% level for WxP	-	1.4884	-	-	1.2077	-	-	1.1908	-
CD at 5% level for PxNa	-	1.8230	-	-	1.479	-	-	1.4584	-

Table-20 Effect of different levels of Na, W and their interactions on volume of expansion

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	2.53	2.51	2.74	1.71	1.98	2.24	1.95	2.34	2.83
W2	2.17	1.88	2.72	1.41	1.39	1.58	1.99	1.89	1.83
Mean for Na	2.34	2.20	2.73	1.56	1.69	1.91	1.97	2.11	2.33
Mean for W1	-	2.58	-	-	1.976	-	-	2.3733	-
Water W2	-	2.26	-	-	1.463	-	-	1.9043	-
CD at 5% level for W	-	0.8593	-	-	0.6973	-	-	0.6875	-
CD at 5% level for Na	-	1.0525	-	-	0.8539	-	-	0.8420	-
CD at 5% level for WxNa	-	1.4885	-	-	1.2077	-	-	1.1908	-

Fig. 8. Effect of different levels of Na, P, Water and their interaction on volume of expansion during third stage.

Fig. 9. Effect of different levels of Na, P, Water and their interaction on porosity during third stage.

Fig 8

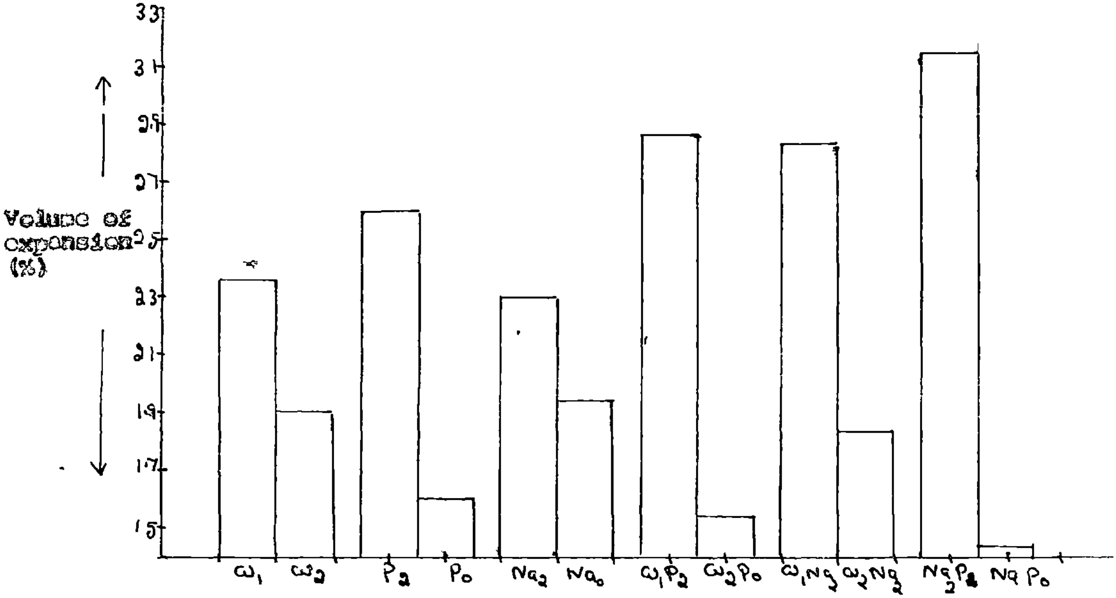
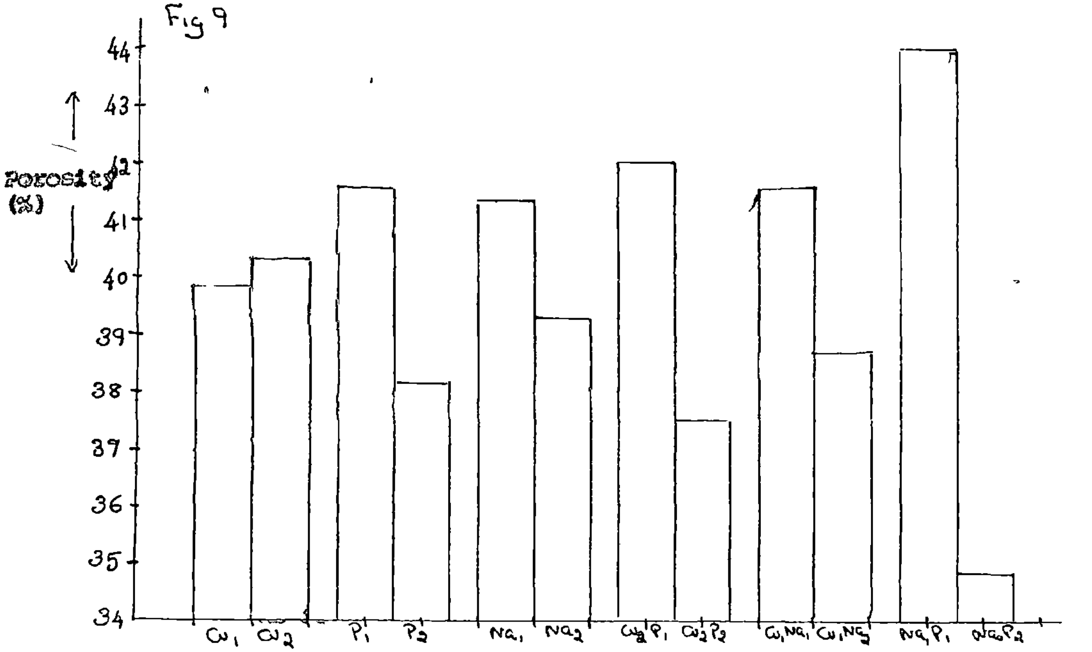

Volume of expansion (%)
33
31
29
27
25
23
21
19
17
15
W1 W2 P2 P0 Na2 Na0 W1P2 W2P0 W1Na2 W2Na2 Na2P2 NaP0

Fig 9


Porosity (%)
44
43
42
41
40
39
38
37
36
35
34
W1 W2 P1 P2 Na1 Na2 W2P1 W2P2 W1Na1 W1Na2 NaP1 NaoP2

of growth maximum combination of sodium and phosphorus (Na_2 P_2) gives highest value of 3.17.

The present study on direct and interaction effect of different treatment show that the higher doses of sodium and phosphorus along with higher level of water increases volume of expansion. Pupisky and Shainberg (1979) in their experimental work indicated that at high ESP and salt concentration above 0.01 N, swelling of clay was the main mechanism responsible for the hydraulic conductivity to decrease. Studies conducted by Gupta and Bhatia (1975) supports this result. They show the behaviour of air permeability at various combination of moisture content and bulk density and it was attributed to (1) reduction in airfilled porosity with increase in moisture content, coupled with swelling of solid phase at the expense of void space, (2) Maximum swelling effects in the moisture content range of 22 to 36 per cent by volume at relatively low bulk density. When water level increased more absorption of water so higher expansion. Sodium at the higher level might have influenced absorption of water in the exchange site thereby increasing volume of expansion.

4.3.3. Porosity

Porosity is determined for all the samples collected from 15 cm depth at the three stages and mean values presented in table No. 21 and 22 and in Fig. 9.

Table-21 Effect of different levels of P, Na, Water and their interactions on pore space (%)

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	43.89	37.39	42.67	40.06	40.60	40.58	39.77	41.09	38886
W2	40.72	42.95	41.87	40.27	42.15	40.76	41.55	42.01	37.54
Na0	41.27	42.36	41.66	40.42	41.95	41.54	40.75	42.35	34.85
Na1	41.47	40.07	43.27	39.99	41.09	40.39	40.42	44.04	39.61
Na2	44.18	38.09	41.88	40.09	41.09	40.09	40.81	38.26	40.14
Mean for P	42.31	40.17	42.27	40.17	41.38	40.67	40.66	41.55	38.18
CD at 5% level for P	-	3.868	-	-	1.2389	-	-	1.3128	-
CD at 5% level for PxW	-	5.471	-	-	1.7521	-	-	1.8566	-
CD at 5% level for PxNa	-	6.7001	-	-	2.1458	-	-	2.2739	-

Table-22 Effect of different levels of Na, Water and their interactions on spore space (%)

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	42.5300	41.23	39.10	40.45	39.94	40.86	39.32	41.61	38.78
W2	39.9930	41.97	43.57	42.15	41.03	39.99	39.31	41.10	40.69
Mean for Na	41.76	41.60	41.38	41.30	40.49	40.43	39.32	41.36	39.73
Mean for W1	-	41.310	-	-	40.416	-	-	39.90	-
Water W2	-	41.847	-	-	41.061	-	-	40.37	-
CD for Water at 5% level	-	3.1584	-	-	1.0116	-	-	1.0719	-
CD for Sodium at 5% level	-	3.8630	-	-	1.2389	-	-	1.3128	-
CD for WxNa at 5% level	-	5.4710	-	-	1.7521	-	-	1.8566	-

Water has no significant effect on any of the three stages for the soil porosity. In the third stage of growth P_0 (40.66) and P_1 (41.55) give a significant value over P_2 (38.18). During the first and second stage different levels of sodium have not affected porosity. During the third stage sodium at a level of 68 g/plant/annum given a significant value (41.36) over Na_0 (39.32) and Na_2 (39.73).

Only interaction of different levels of water and phosphorus has influenced value of porosity during the first stage of growth. W_1 P_0 gives the highest value of 43.9 and minimum value is for W_1 P_1 (37.39). In the second stage maximum value is for W_2 P_1 (42.20) and minimum value is 40.00 for W_1P_0. During the yielding stage higher dose of phosphorous and ~~higher~~ lower levels of water show a lower value for porosity (37.54) while P_1W_2 give the highest value of 42.01. Sodium and water in combination at the lowest level gives maximum value of porosity (42.20) during the second stage. For this interaction values ranges from 39.9 to 42.2. Na_1 with two levels of water is recorded significant value of porosity (41.61 and 41.10) which is significant over W_1 Na_2 and on par with W_2 Na_2. The interaction of sodium and phosphorus has no significance over first and second stage. But a significant value of 44.04 is obtained for Na_1 P_1 during the third stage of growth. Here value ranges from 34.9 (Na_0P_2) to 44.04.

In all the three seasons sodium at an optimum level Na_1 is found to have an influence on porosity of the soil. With no sodium and higher level of sodium the porosity is found to decrease in many of the treatments. Pupisky and Shainberg (1979) have shown that at low ESP and very dilute soil solution, dispersion and clay migration within the conductivity pores were the main mechanism responsible for plugging the soil pores. Different levels of phosphorus or its interaction have no much influence on the porosity of soil. Higher values of porosity for medium dose of phosphorus and sodium treatments may be due to increase in micropores over macropores. Microporosity mainly count the porosity of soil. Pandey and Pathek (1975) found that high sodium saturation in soil increase bulk density and decrease non-capillary porosity resulting in low hydraulic conductivity. In the present study the highest dose of Na_2 decreased the microporosity and Na_1 is found to be favourable for optimum porosity.

4.3.6. Mean weight diameter

Mean values of the mean weight diameter calculated from the wet sieving aggregate analysis, done for the pooled samples collected from 15cm depth at three stages of growth of the plant, are presented in the table No. 23. The statistical analysis is not done for these pooled data, but correlation is given in table No. 43, 44 and 45 and in Fig. 10.

Table-23 Effect of different levels of Na, P, W and their interactions on the mean weight diameter and Hydraulic conductivity

Treatments	Mean weight diameter I stage	Mean weight diameter II stage	Mean weight diameter III stage	Hydraulic conductivity (3rd stage) cm h^{-1}
W1 P0 Na0	0.9363	0.5390	0.4870	68.62
W1 P0 Na1	0.8294	0.3299	0.5690	35.54
W1 P0 Na2	1.0528	0.4932	0.6391	77.12
W1 P1 Na0	0.5723	0.5131	0.5371	75.84
W1 P1 Na1	0.8079	1.1402	0.9312	56.08
W1 P1 Na2	1.1784	0.9555	0.9837	76.40
W1 P2 Na0	0.5240	1.1394	0.7833	37.54
W1 P2 Na1	0.6348	0.7492	0.6891	130.05
W1 P2 Na2	0.6325	0.9763	0.8391	93.25
W2 P0 Na0	0.6560	0.8523	0.4081	71.05
W2 P0 Na1	0.3973	0.8541	0.3891	47.71
W2 P0 Na2	0.4446	0.9442	0.3923	66.63
W2 P1 Na0	0.5313	1.3392	0.4391	127.39
W2 P1 Na1	0.6299	0.9818	0.5276	97.30
W2 P1 Na2	0.7133	0.8011	0.6912	57.71
W2 P2 Na0	0.4643	0.6803	0.3982	30.61
W2 P2 Na1	0.8884	0.5741	0.4839	37.82
W2 P2 Na2	0.3833	0.7272	0.3971	111.09
Mean				
P0	0.7196	0.6691	0.4808	61.15
P1	0.7439	0.9552	0.6849	81.79
P2	0.5679	0.8078	0.5985	73.38
Na0	0.6142	0.8439	0.5086	68.51
Na1	0.6979	0.7716	0.5973	67.42
Na2	0.7342	0.8166	0.6571	80.39
W1	0.7965	0.7598	0.7176	72.27
W2	0.5677	0.8616	0.4585	1.94

In the first season with no phosphorus for an increase in sodium content there is an increase in mean weight diameter. With increase in phosphorus from P_1 to P_2 there is a decrease in mean weight diameter from 0.7439 to 0.5879. Maximum values of 1.0528 (P_0 Na_2) and 1.1784 (P_1 Na_2) and minimum values of 0.3833 (P_2Na_2) and 0.3973 (P_0Na_1) are recorded. Water level has no effect in the first and second stages.

In the second stage P_1 Na_1 shows comparatively high values 1.1402 and 0.9818 where as lower values given by P_0Na_1 (0.3299). There is a decrease in mean weight diameter with increase in sodium content from Na_0 to Na_1. Na_0 has got highest value (0.8439).

In the third stage water level has significant influence. For the higher level of water there is an increase in mean weight diameter. Here also the effect of sodium has got same trend as in the second stage. But with phosphorus at the rate of 90 g/plant/annum gives the maximum value for mean weight diameter. Maximum value noted for $W_1P_1Na_2$ is 0.9837.

From the correlation matrix (Table No. 43, 44 and 45) it can be seen that mean weight diameter is positively correlated with soil phosphorus and negatively correlated with moisture in the second and third stages. Gattani <u>et al</u>., (1976) through various experiment found that phosphorus fertilizer had a beneficial effect on aggregation which is in

Fig. 10. Effect of different levels of Na, P, Water and their interaction on mean weignt diameter during third stage.

Fig. 11. Effect of different levels of Na, P, Water and their interaction on hydraulic conductivity during 3rd stage.

Fig.10

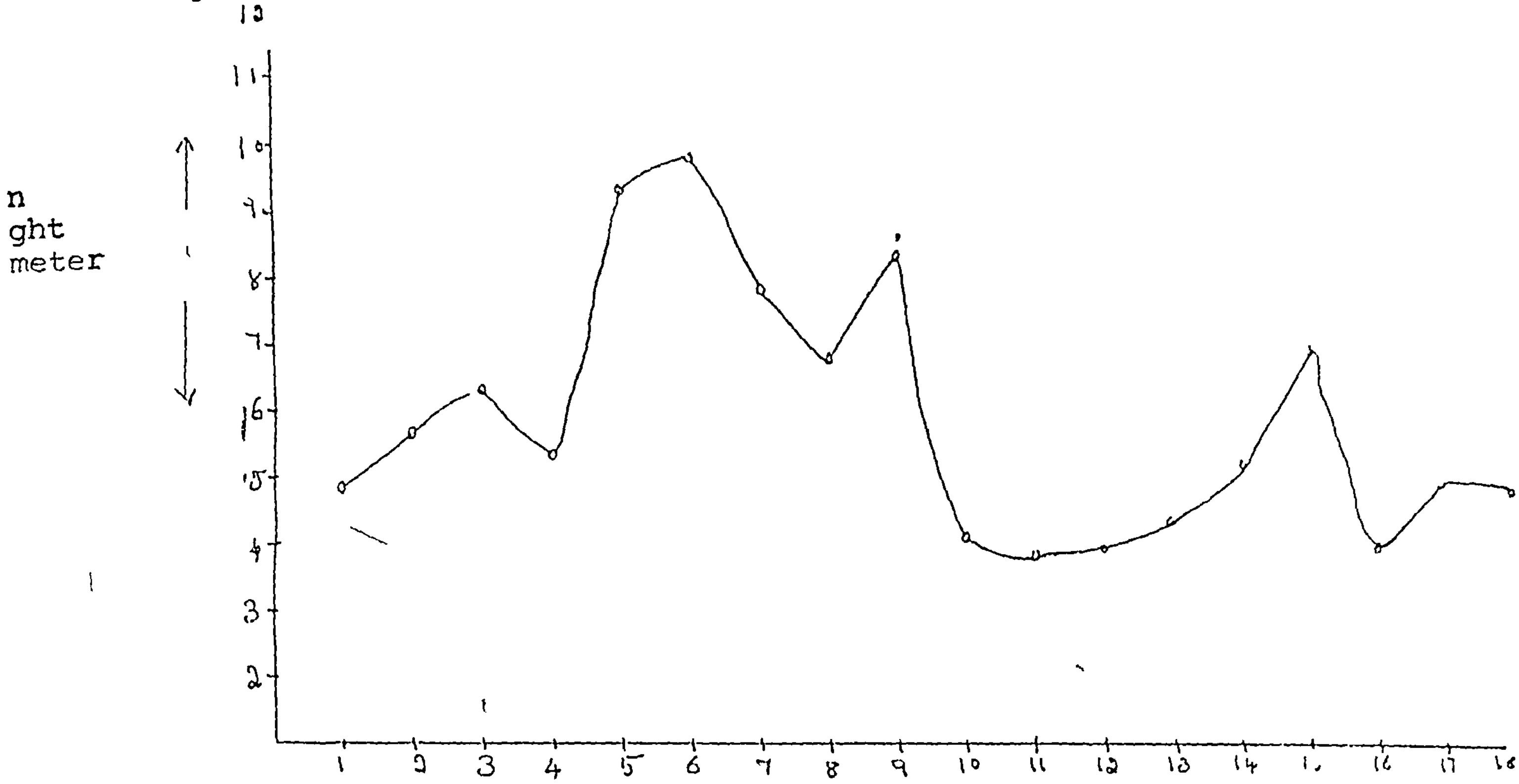
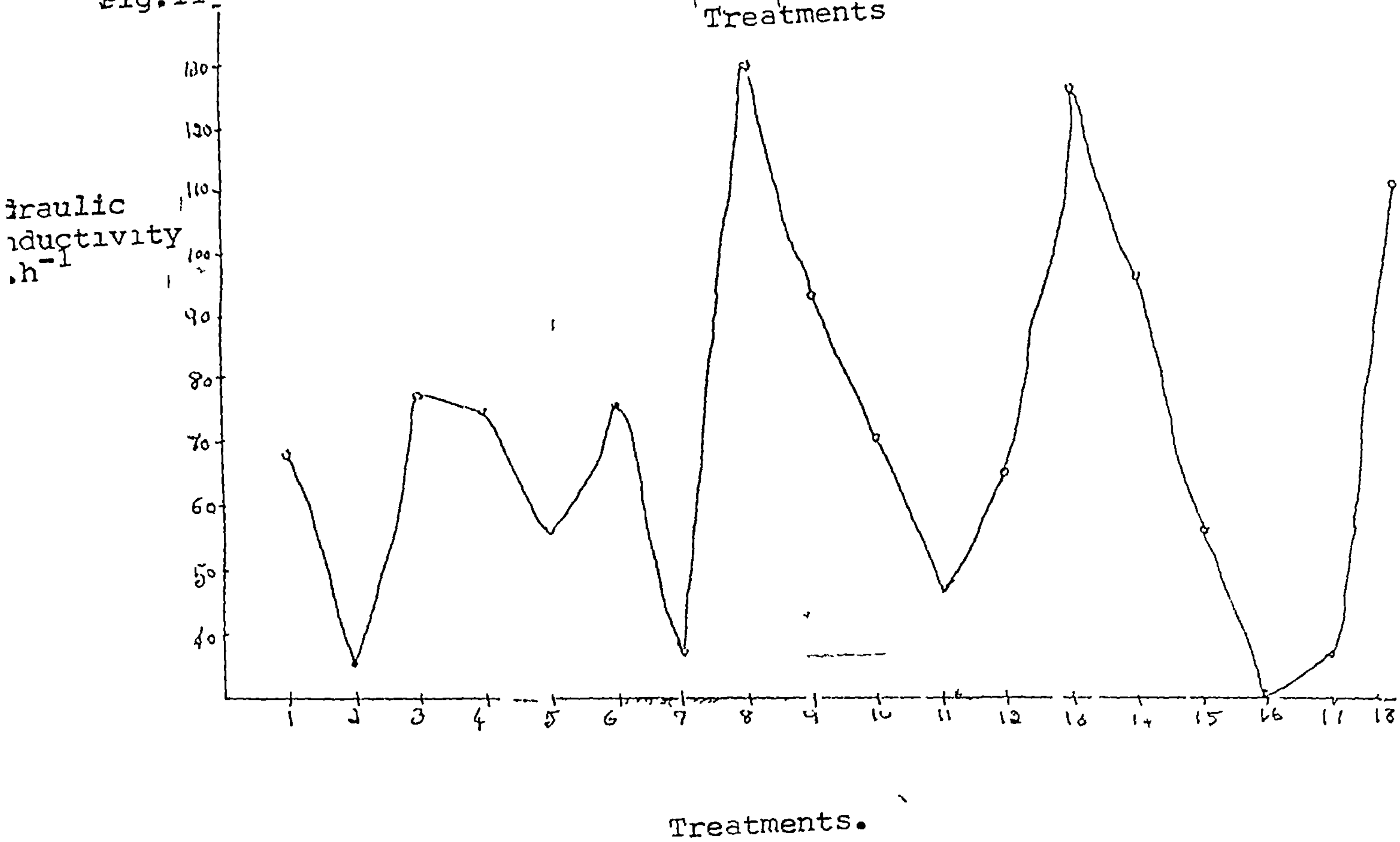


Fig.11



confirmity with this result. Chibber ~~et al~~. (1964) has concluded that water stable aggregates are directly related to moisture content while (Gattani (1976) has shown an increase in aggregate stability by the addition phosphorus fertilizers. These results are in confirmity with the present observations obtained.

4.3.7. Hydraulic conductivity

For the third stage, the hydraulic conductivity determined for the pooled sample and presented in table No. 23 and Fig. 11.

Water level has got a significant effect on the hydraulic conductivity of the soil. With higher levels of water there is an increase in hydraulic conductivity (72.27 cm h^{-1}). With increase in phosphorus from P_0 to P_1 there is an increase in hydraulic conductivity. Sodium with P_2 level there is an increase of hydraulic conductivity from 37.54 for $W_1P_2Na_0$ to 130.05 for $W_1P_2Na_1$. For the treatment P_2Na_0 lower values of 37.54 and 30.61 are obtained for the water levels W_1 and W_2 respectively.

When soil received water treatments, higher water level at the rate of 20 per cent depletion of field capacity give a high value of hydraulic conductivity. So in the presence of more water, conductivity increase. Gumbs and Warkentin (1975) reported, higher values for diffusivities and conductivities on wetting than on drying and generally larger in unconfined than in confined samples. At higher water content interference of sodium is less and a higher value of hydraulic conductivity is obtained. Sodium in soil solution helps in soil aggregation. Thereby increase the values of hydraulic conductivity at Na_1 level. This result is in agreement with the works of many scientists like Dixit and Lal (1972). Govinda Iyer (1957), Klagga (1966) and Sharma (1972), they all reported that an increase in exchangeable sodium percentage is accompanied by a marked decrease in hydraulic conductivity ie. at very high levels of sodium.

4.4. Chemical properties

Chemical analysis of the soil collected from a depth of 15 cm at all the three stages of plant growth are done and mean values are presented in table No. 24 to 38.

Results are given for organic carbon, available and total, nitrogen, phosphorus and potassium and exchangeable calcium, magnesium and sodium. Plant analysis is carried out for total nitrogen, phosphorus, potassium, calcium, magnesium and sodium. Tables 39 to 42 give results of plant analysis.

4.4.1. Organic carbon

Table 24 and 25 give mean values of organic carbon for different stages of plant growth.

Table-24 Effect of different levels of P, Na, W and their interactions on organic carbon (%)

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	1.0965	0.8686	0.9362	0.5745	0.6021	0.4362	0.5044	0.5450	0.3545
W2	0.8640	0.9856	0.7515	0.5990	0.4731	0.4424	0.5585	0.4705	0.4226
Na0	1.2520	1.0256	0.7577	0.5483	0.6082	0.4101	0.5148	0.6079	0.3119
Na1	0.7947	0.7484	1.0257	0.5299	0.4839	0.4932	0.4969	0.4431	0.5067
Na2	0.9240	1.0072	0.7483	0.6820	0.5207	0.4147	0.5827	0.4858	0.3479
Mean P	0.9903	0.9273	0.5439	0.5068	0.5376	0.4393	0.5315	0.5123	0.3886
CD for P at 5% level	-	0.3098	-	-	0.1686	-	-	0.1184	-
CD at 5% level for PxW	-	0.4381	-	-	0.2385	-	-	0.1675	-
CD at 5% level for PxNa	-	0.5365	-	-	0.2921	-	-	0.2051	-

Table-25 Effect of different levels of Na, Water and their interactions on organic carbon

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	1.0533	0.9055	0.9424	0.5591	0.5161	0.5376	0.4443	0.4455	0.5141
W2	0.9702	0.8070	0.8439	0.4854	0.4885	0.5407	0.5121	0.5189	0.4296
Mean for Na	1.0118	0.8563	0.8931	0.5222	0.5023	0.5391	0.4782	0.4822	0.4718
Mean for Water W1	-	0.9671	-	-	0.5376	-	-	0.4683	-
W2	-	0.8737	-	-	0.5046	-	-	0.4869	-
CD at 5% level for Na Water	-	0.2529	-	-	0.1377	-	-	0.0967	-
CD at 5% for Na	-	0.3093	-	-	0.1686	-	-	0.1184	-
CD for WxNa at 5% level	-	0.4381	-	-	0.2385	-	-	0.1675	-

The different levels of water, phosphorus and sodium have no effect on organic carbon content. The no phosphorus treatment shows a higher value for organic carbon than P_1 and P_2.

For the first two stages there is no significant interaction effect of different levels of phosphorus and water on organic carbon. During the third stage W_2P_0 gives maximum value of 0.56 which is significant over W_1P_2 (0.35). Organic carbon content is not influenced by the interaction of water and sodium in any of the stages. Sodium and phosphorus interaction do not change the organic carbon content during the initial stages of growth. At the yielding stage for this interaction the values ranges from 0.32 for Na_0P_2 to 0.61 for Na_0P_1. The maximum value is significant over Na_0P_2 (0.32), Na_2P_2 (0.35) and Na_1P_1 (0.44).

Satisfactory values of organic carbon are obtained even in the absence of phosphorus for all the three stages. There is a degradation in soil organic carbon from first stage to third stage probably due to utilization by the plant. As phosphorus level increased from P_0 to P_2 there is a slight decrease in organic carbon in almost all the treatments throughout plant growth.

4.4.2. Soil nitrogen (Available)

Available nitrogen content are determined at different

Table-26 Effect of different levels of P, Na, Water and their interactions on available nitrogen (in kg ha^{-1})

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	280.72	283.23	270.89	171.24	172.98	184.68	173.95	143.49	175.06
W2	304.76	548.80	233.94	172.98	175.61	173.72	147.59	149.02	355.64
Na0	233.67	475.78	237.44	170.99	169.86	174.72	174.50	131.51	197.57
Na1	215.53	337.12	240.57	173.60	174.57	189.28	149.89	152.54	158.95
Na2	428.99	435.16	279.25	171.73	178.45	173.60	157.92	154.71	439.53
Mean P	292.73	416.02	252.43	172.11	174.30	179.20	160.77	146.26	265.35
CD at 5% level for P	-	166.05	-	-	22.29	-	-	157.13	-
CD at 5% level forWXP	-	234.82	-	-	31.54	-	-	222.22	-
CD at 5% level for PxNa	-	287.60	-	-	38.62	-	-	272.16	-

Table-27 Effect of different levels of Na, Water and their interactions on available nitrogen

		I stage			II stage			III stage		
		Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1		239.50	257.20	338.14	171.24	182.19	175.47	170.16	167.22	154.61
W2		391.75	271.61	424.13	172.48	176.11	173.72	165.55	139.87	346.83
Mean for Sodium		315.63	264.41	381.14	171.86	179.15	174.60	167.84	153.80	250.72
Mean for	W1	-	278.2800	-	-	176.30	176.30	-	164.14	-
Water	W2	-	362.4990	-	-	174.11	-	-	217.42	-
CD at 5% level for Water		-	135.5800	-	-	18.2072	-	-	128.29	-
CD at 5% level for Sodium		-	166.0450	-	-	22.2990	-	-	157.13	-
CD at 5% level for WxNa		-	234.82	-	-	31.54	-	-	222.22	-

stages of plant growth and presented the mean values in tables 26 to 27 and in figure 12.

Individual effects of water, phosphorus and sodium levels are negligible on available nitrogen. For different levels of phosphorus and water combination maximum response for P_1W_2 (548.8) this is significant over all the other combination of phosphorus and water during the first stage of growth.

In the second and third stage of growth there is no interaction effect excepting the effect of Na_2P_2 on available nitrogen, in the third stage. All the other interaction at the third stage are insignificant. Na_2P_3 gives highest value of available nitrogen (439.5) which is significant over all the other treatment combinations. The effect of treatments on available nitrogen are predominent only during the third stage. There is a decrease in available nitrogen content of soil from initial stages to yielding stage of plant growth. Stumpe et al. (1984) reported from his experiment that addition of urea with phosphate slightly decreased ammonia loss from 17.0 to 12.2 per cent of the applied nitrogen on a highly calcarious soil. In the present case also the losses of nitrogen might have been reduced to same content by the increased levels of phosphorus.

Fig. 12. Effect of different levels of Na, P, Water and their interaction on soil available nitrogen during third stage.

Fig. 13. Effect of different levels of Na, P, Water and their interaction on soil available phosphorus during second and third stage.

Fig 12

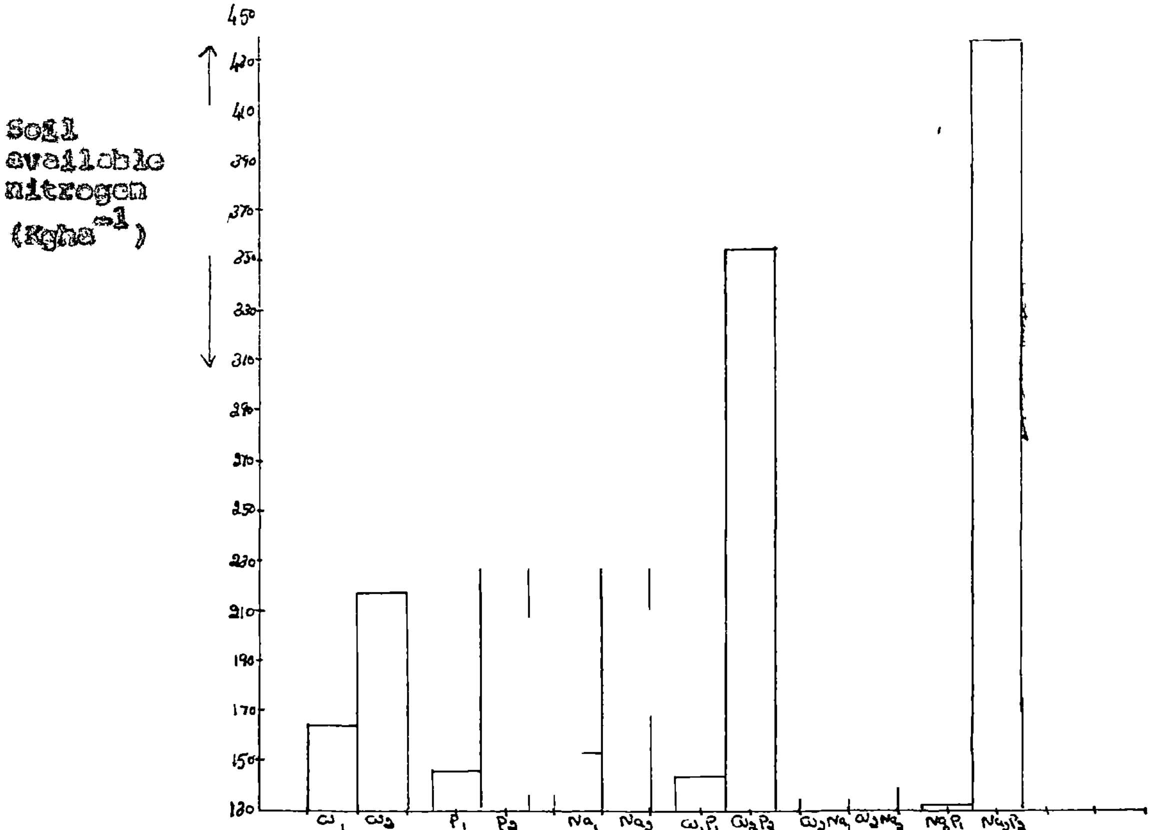
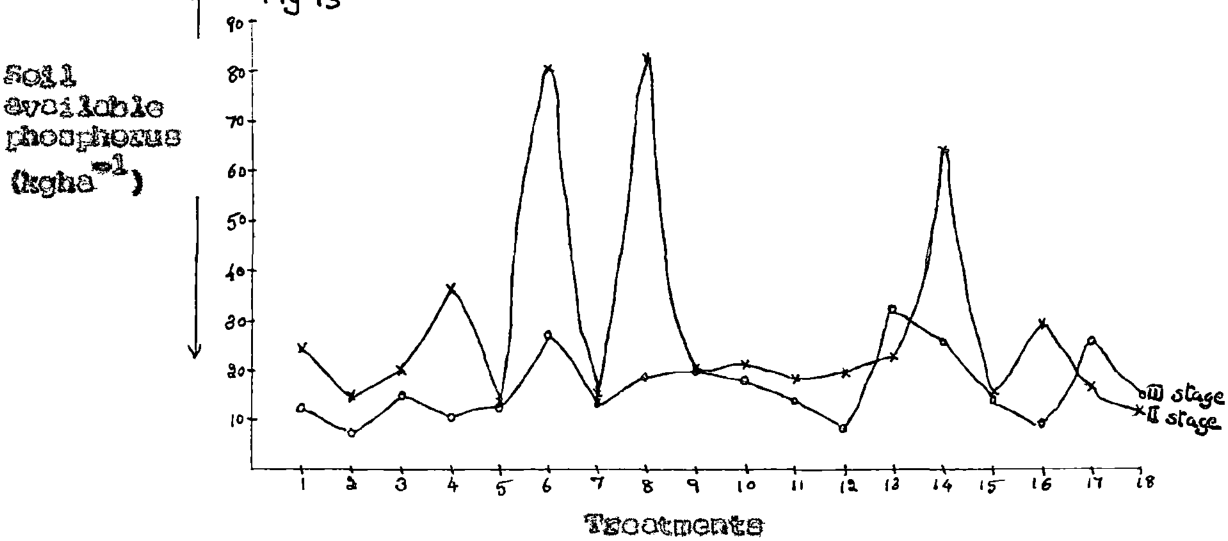

Soil available nitrogen (Kgha^{-1})
W_1
W_2
P_1
P_2
Na_1
Na_2
W_1P_1
W_2P_2
W_2Na_1
W_2Na_2
NaP_1
NaP_2

Fig 13


Soil available phosphorus (kgha^{-1})
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
III stage
II stage
Treatments

4.4.3. Soil phosphorus (Available)

Analytical results of available phosphorus are given in table 28 and 29 as mean values, and figure 13.

In all the three stages there is no individual effect for different levels of phosphorus, sodium and water. There is no significant effect due to interactions excepting the different levels of sodium and phosphorus in the first stage of growth. In the initial stage Na_1P_0 which has got maximum available phosphorus of 20.3 kg P ha^{-1} which is significant over all the other combination of sodium and phosphorus excepting Na_2P_1 (15.6) and Na_3P_1 (13.0). Maximum values of available phosphorus are observed during second stage.

From the results obtained for available phosphorus, is phosphorus applied at the rate of 90 g/plant/annum is found to be a better treatment as far as availability or phosphorus concerned. When the sodium level is increased to Na_2 there is a slight increase in the value of available phosphorus. Available phosphorus analysed during second stage is found to be maximum and it in decreased when plant attain maturity. The initial analysis shows a low value for available phosphorus since the applied fertilizer is not made available to plant at that time. When the water treatments are given, for water level at 40% depletion from field capacity available phosphorus is found to increase. Even at lower water levels the available phosphorus

Table-28 <u>Effect of different levels of P, Na, Water and their interactions on soil available phosphorus</u>

(in kg ha^{-1})

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	11.49	10.91	8.64	19.93	43.65	39.67	11.56	16.82	17.56
W2	13.82	14.25	8.99	19.83	34.30	19.39	12.99	24.24	16.49
Na0	8.07	13.05	9.77	22.82	29.77	22.48	15.14	21.77	10.77
Na1	20.33	9.08	9.04	16.72	38.96	49.79	10.53	10.33	22.31
Na2	9.57	15.62	7.63	20.09	48.20	16.33	11.16	20.49	17.99
Mean P	12.66	12.58	8.81	19.87	38.98	29.53	12.28	20.53	17.03
CD at 5% level for Phosphorus	-	5.20	-	-	23.90	-	-	10.81	-
CD at 5% level for WxP	-	7.36	-	-	33.83	-	-	15.28	-
CD at 5% level for PxNa	-	9.01	-	-	41.43	-	-	18.72	-

Table-29 <u>Effect of different levels of Na, Water and their interactions on soil available phosphorus</u>

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	9.38	11.63	10.02	25.36	37.24	40.64	11.97	12.91	21.06
W2	11.21	14.00	11.85	24.69	33.07	15.77	19.82	21.87	12.03
Mean for sodium	10.30	12.82	10.94	25.02	35.16	28.21	15.89	17.39	16.55
Mean for water W1	-	10.34	-	-	34.41	-	-	15.32	-
W2	-	12.36	-	-	24.51	-	-	17.91	-
CD at 5% level for Water	-	4.25	-	-	19.53	-	-	8.82	-
CD at 5% level for Na	-	5.201	-	-	23.92	-	-	10.81	-
CD at 5% level for WxNa	-	7.36	-	-	33.83	-	-	15.28	-

is found to give a higher value in this result is contridictory to the observations by Vyas and Motiramani (1971) where they found an increase in available phosphorus content, for an increase in moisture content. The availability of phosphorus at lower levels of water can be attributed to the higher sodium levels, which might have overcome the lower water situations. From the correlation matrix (Table No. 43). Positive correlation is observed between mycorrhizal population and available phosphorus in the first stage (24%). This correlation is not seen during later stages. Levels of mycorrhizal infection on Leucene roots increased on the concentration of phosphorus was raised from 0.002 to 0.153 $\mu g\ ml^{-1}$ (Habte and Manjunath 1987). This work also agrees with the result of the experiment. Effect of sodium on available phosphorus is positive during the first and third stages. This result is in confirmity with the work of Barrow and Shaw (1979) that by mixing phosphated soil with solutions of chloride salts desorption of phosphorus was faster in sodium chloride than magnesium chloride and calcium chloride. There is negative correlation in the second stage of growth where the available phosphorus was maximum. As the sodium level increased the uptake of phosphorus is not influenced by the mycorrhizal population. Strullu et al., (1986) from their work come to the conclusion that the rate of uptake of phosphate was not increased by sodium and potassium in the presence of mycorrhizal fungi which is in consonance witn the present result.

4.4.4. Soil Potassium (Available)

Soil available potassium is determined at 15cm depth for all stages of growth and mean values in kg/ha as K are presented in table 30 and 31 and in figure No. 14.

Sodium, water and phosphorus alone as such is not bringing any change in the values of available potassium. There is no much changes observed in available potassium during the first and second stage, for the interaction of water and phosphorus. Later stages values ranges from 13.2 to 25.6. Maximum value is obtained for P_2W_1 and minimum for P_1W_1. Sodium and water interaction has no significant effect. Significant effect of sodium and phosphorus interaction is noted only during the third stage, where Na_1P_2 gives significant value (28.17) over Na_2P_1(14.94) Na_2P_0 (13.21), Na_0P_2 (12.88) and Na_1P_1 (10.04). Values ranges from 10.04 to 28.17.

Potassium from first stage of growth decrease suddenly during second stage and further reduce during third stage of growth. The higher values obtained during the first stage are due to the fact that the samples are collected for analysis after the application of fertilizer. The gradation in the potassium level towards later stages might be due to leaching losses, plant absorption and fixation. During later stages, Table-30 Effect of different levels of P, Na, W and their interactions on available potassium on soil (k)

(in kg h^{-1})

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	189.77	145.97	144.06	70.02	64.11	70.62	20.18	13.16	25.60
W2	153.55	144.97	159.79	61.48	70.84	65.00	17.61	18.25	16.32
Na0	163.14	153.96	139.24	60.46	64.42	74.23	21.97	22.13	12.88
Na1	154.27	129.25	172.73	66.95	72.85	62.45	21.48	13.04	28.17
Na2	197.59	153.22	142.91	59.84	65.16	66.75	13.22	14.94	21.82
Mean P	171.67	145.47	151.63	65.75	67.48	67.81	18.89	15.71	20.96
CD at 5% level for Phosphorus	-	50.75	-	-	11.29	-	-	7.56	-
CD at 5% level for WxP	-	71.77	-	-	15.97	-	-	10.69	-
CD at 5% level for PxNa	-	87.90	-	-	19.56	-	-	13.09	-

Table-31 Effect of different levels of Na, W and their interactions on soil available potassium (k)

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	137.06	189.50	153.25	60.43	56.08	69.25	21.56	19.26	18.07
W2	167.16	114.66	175.89	63.32	68.75	65.26	16.39	20.53	15.25
Mean for Sodium	152.11	152.03	164.57	65.37	67.42	67.25	18.99	19.89	16.66
Mean for Water W1	-	159.94	-	-	68.25	-	-	19.64	-
W2	-	152.57	-	-	65.78	-	-	17.39	-
CD at 5% level for Water	-	41.44	-	-	9.22	-	-	6.17	-
CD at 5% level for Sodium	-	50.75	-	-	11.29	-	-	7.56	-
CD at 5% level for WxNa	-	71.77	-	-	15.97	-	-	10.69	

Fig. 14. Effect of different levels of Na, P, Water and their interaction on soil available potassium during third stage.

Fig. 15. Effect of different levels of Na, P, Water and their interaction on soil available sodium during all the stages.

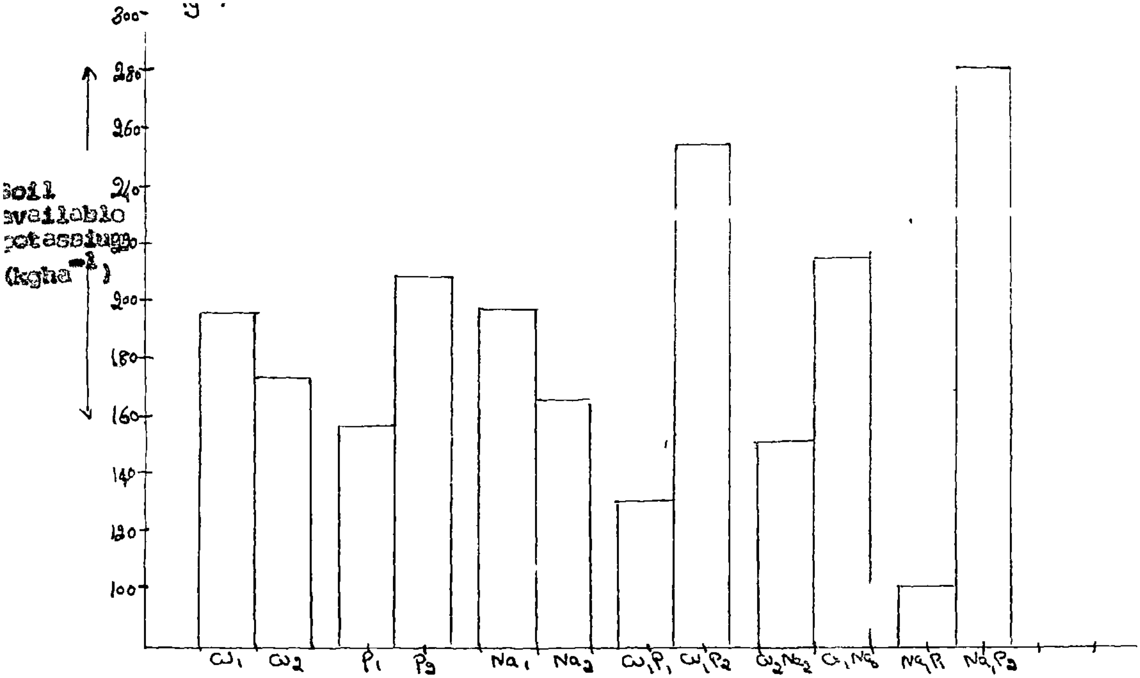
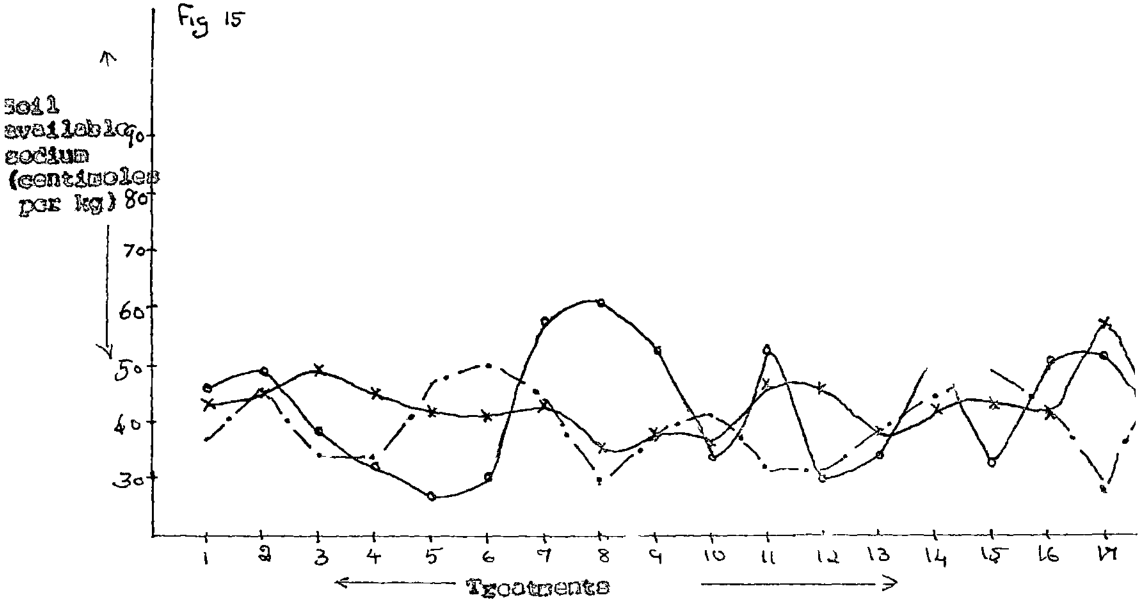

Soil available potassium (kgha-1)
300
280
260
240
200
180
160
140
120
100
W1
W2
P1
P2
Na1
Na2
W1P1
W1P2
W2Na2
W1Na2
Na2P1
Na1P2

Fig 15


Soil available sodium (centimoles per kg)
90
80
70
60
50
40
30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Treatments

as the phosphorus level increases from P_0 to P_2, available potassium content increases in soil. The work of Gillman and Fox (1980) observed that with increase in superphosphate application the leaching loss of calcium, magnesium and potassium was retarded.

4.4.5. Soil calcium and magnesium (Exchangeable)

Calcium and magnesium for all three stages at a depth of 15 cm are determined using atomic absorption spectrometer and is given as centimoles(+) kg^{-1} in tables 32 to 35.

The separate effects of water, phosphorus and sodium have not made any change in exchangeable calcium and magnesium in the first stage. In the case of calcium, phosphorus in the control dose (.0027) has got significance over first dose of phosphorus P_2 (.0032) in the second stage. In the case of magnesium sodium has some influence on magnesium. In the second stages sodium at the rate of Na_1 and Na_2 is significant over no sodium.

In the first stage for exchangeable calcium the maximum value is obtained for W_2P_1 (.0045) while the minimum value is given by W_2P_0 (.0036). The same trend is noted in the second stage of growth also. Here the minimum value is given by W_1P_0 (.0026).

In the first stage of growth there is no significant change on exchangeable magnesium by any of the interaction

Table-32 Effect of different levels of P, Na, Water and their interactions on soil exchangeable calcium

Centimole(+) kg^{-1}

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	0.0044	.0040	.0040	.0026	.0028	.0029	.0003	.0005	.0006
W2	0.0036	.0045	.0042	.0027	.0036	.0029	.0005	.0007	.0005
Na0	0.0039	.0043	.0039	.0022	.0030	.0025	.0002	.0007	.0002
Na1	0.0043	.0040	.0046	.0041	.0033	.0036	.0005	.0005	.0010
Na2	0.0038	.0045	.0036	.0026	.0033	.0026	.0005	.0004	.0004
Mean P	0.0040	.0043	.0041	.0027	.0032	.0029	.0004	.0006	.0005
CD at 5% level for Phosphorus	-	.00047	-	-	.00067	-	-	.0004	-
CD at 5% level for WxP	-	.00067	-	-	.00095	-	-	.00056	-
CD at 5% level for PxNa	-	.00082	-	-	.00012	-	-	.00069	-

Table-33 Effect of different levels of Na, Water and their interactions on soil exchangeable calcium

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	0.0040	0.0044	0.0039	0.0026	0.0034	0.0023	0.0003	0.0006	0.0006
W2	0.0041	0.0042	0.0040	0.0026	0.0032	0.0034	0.0005	0.0007	0.0004
Mean for Sodium	0.0041	0.0043	0.0040	0.0026	0.0033	0.0028	0.0004	0.0006	0.0005
Mean for W1	-	0.0041	-	-	0.0028	-	-	0.0005	-
Water W2	-	0.0041	-	-	0.0031	-	-	0.0005	-
CD at 5% level for Water	-	0.000385	-	-	0.00055	-	-	0.00033	-
CD at 5% level for Sodium	-	0.0004176	-	-	0.00067	-	-	0.000398	-
CD at 5% level for WxNa	-	0.00066	-	-	0.00095	-	-	0.00056	-

levels. In the second stage of growth maximum exchangeable magnesium is noted in the W_2P_1 (.0008) which is significant over all other treatment. In the third stage W_2P_2 has got a high value of .0008 which is significant over W_1P_1 (.0004). Maximum magnesium is present in W_1P_0 (.0009). In the case of exchangeable calcium there is no significant effect produced by water and sodium combination during first and third stages. In the second stage among the treatments highest value given by W_1Na_1 (.0034) and it is on par with W_2Na_2 (.0034) and W_2Na_1 (.0032) and it is significant over W_1Na_2 (.0023). In the case of magnesium maximum values are noted in W_1Na_1 (.0008) and W_2Na_2 (.0008) which is significant over W_1Na_0 (.0006) and W_1Na_2 (.0006) during the second stage. During the last stages of growth maximum value for magnesium is for W_2Na_0 (.001).

For different levels of sodium and phosphorus in combination during the second stage maximum exchangeable magnesium noted in Na_1P_0 (.0008). During the third stage Na_1P_2 has the highest magnesium (0.001). In the case of exchangeable calcium in the first stage from the interaction effect of sodium and phosphorus, the combination of sodium at the rate of 68 g/plant/annum with phosphorus 115 g/plant/annum giving highest value of .0046, which is on par with Na_2P_1 (.0045) and is significant over Na_2P_2 (.0036) which is having the minimum value. The same trend is obtained during the second and third stage

Table-34 <u>Effect of different levels of P, Na, Water and their interactions on soil exchangeable magnesium</u>

(in centimoles kg^{-1})

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	.0018	.0014	.0016	.0007	.0007	.0007	.0009	.0004	.0007
W2	.0017	.0016	.0016	.0007	.0008	.0007	.0007	.0007	.0008
Na0	.0019	.0014	.0017	.0007	.0007	.0006	.0008	.0009	.0007
Na1	.0017	.0016	.0017	.0008	.0007	.0007	.0009	.0002	.0010
Na2	.0016	.0016	.0014	.0007	.0007	.0006	.0005	.0005	.0005
Mean for Phosphorus	.00175	.0015	.0016	.0007	.00075	.0007	.00080	.00055	.00075
CD at 5% level for Phosphorus	-	.000443	-	-	.00010	-	-	.0004	-
CD at 5% level for WxP	-	.00063	-	-	.00014	-	-	.00057	-
CD at 5% level for PxNa	-	.00077	-	-	.00018	-	-	.00069	-

Table-35 <u>Effect of different levels of Na, Water and their interactions on exchangeable magnesium</u>

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	.0015	.0019	.0014	.0006	.0008	.0060	.0006	.0006	.0007
W2	.0018	.0015	.0016	.0007	.0007	.0008	.001	.0007	.0004
Mean for Sodium (Na)	.0017	.0017	.0015	.0006	.0007	.0007	.0008	.0007	.0006
Mean for Water W1	-	.0016	-	-	.0007	-	-	.0007	-
Mean for Water W2	-	.0016	-	-	.0007	-	-	.0007	-
CD at 5% level for Water (W)	-	.00036	-	-	.000082	-	-	.00033	-
CD at 5% level for Sodium (Na)	-	.00044	-	-	.00010	-	-	.0004	-
CD at 5% level for WxNa	-	.00063	-	-	.00014	-	-	.00057	-

of growth where Na_1P_2 combination giving highest values of 0.0036 and 0.001.

Sodium at the optimum level ie. sodium at the rate of 68 g/plant/annum with a highest phosphorus level of 115 g/plant/annum has much influenced the exchangeable calcium and magnesium present in the soil. There are reports that in the presence of sodium the calcium and magnesium availability increased. Bladel and Gheyl (1980) have reported that enthalpy and entropy changes were negative for the substitution of calcium by sodium. This favours the replacement of calcium by sodium. In this study also the calcium is released by the sodium present in the soil solution.

4.4.6. Soil sodium (Exchangeable)

Sodium has been applied as sodium chloride as per the treatments, the analysis of sodium become important for the present study. Exchangeable sodium is extracted for soil samples at a depth of 15 cm and analysed using ammonium acetate extract. Mean values obtained for various treatment are depicted in tables 36 and 37 and figure 15.

During the first and second stages of plant growth the various levels of water, phosphorus and sodium do not affect the exchangeable sodium content in the soil. In the later stages of growth lower water content cause an increase in sodium content of soil to $.50 \times 10^{-4}$. Among the phosphorus levels

Table-36 Effect of different levels of P, Na, Water and their interactions on soil exchangeable sodium

($\times 10^{-4}$)in centimole(+) kg^{-1}

	I stage			II stage			III stage		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	0.39	0.44	0.37	0.46	0.43	0.39	0.45	0.30	1.0
W2	0.35	0.44	0.39	0.43	0.41	0.47	0.39	0.41	0.47
Na0	0.39	0.36	0.43	0.40	0.42	0.43	0.40	0.33	1.0
Na1	0.44	0.46	0.28	0.46	0.43	0.38	1.00	0.40	1.0
Na2	0.33	0.50	0.43	0.48	0.42	0.40	0.35	0.32	0.46
Mean for Phosphorus	0.37	0.44	0.38	0.45	0.42	0.43	0.42	0.36	0.74
CD at 5% level for Phosphorus	-	0.1230	-	-	0.0812	-	-	0.1420	-
CD at 5% level for WxP	-	0.1740	-	-	0.1149	-	-	0.2002	-
CD at 5% level for PxNa	-	0.2120	-	-	0.1407	-	-	0.2450	-

Table-37 Effect of different levels of Na, W and their interactions on soil exchangeable sodium

	I stage			II stage			III stage		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	0.38	0.41	0.41	0.44	0.41	0.43	0.46	0.46	0.41
W2	0.40	0.34	0.43	0.38	0.49	0.44	0.40	1.00	0.34
Mean for Sodium	0.20	0.38	0.42	0.41	0.45	0.44	0.43	0.73	0.38
Mean for Water W1	-	0.40	-	-	0.43	-	-	0.36	-
Mean for Water W2	-	0.39	-	-	0.44	-	-	0.50	-
CD at 5% level for Water	-	0.1000	-	-	0.67	-	-	0.1156	-
CD at 5% level for Sodium	-	0.1230	-	-	0.0813	-	-	0.142	-
CD at 5% level for WxNa	-	0.174	-	-	0.1149	-	-	0.2002	-

phosphorus at the rate of 115 g/plant/annum gives significant values of exchangeable sodium $.74 \times 10^{-4}$ over P_0 ($.42 \times 10^{-4}$) and P_1 ($.36 \times 10^{-4}$). Considering different levels of sodium, Na_1 treatment ($.73 \times 10^{-4}$) is significant over Na_0 ($.43 \times 10^{-4}$) and Na_2 ($.38 \times 10^{-4}$).

Interaction effect of water and phosphorus has changed the values during the third stage of growth only. W_1P_2 gives the maximum value (1×10^{-4}) and minimum value is given by W_1P_1 ($.3 \times 10^{-4}$).

Different levels of sodium and water interaction influence exchangeable sodium during second and third stage. In both stages W_2Na_1 is found to have maximum values ($.49 \times 10^{-4}$) and (1×10^{-4}). These two values are significant over others.

Different combination of sodium and phosphorus level influenced the sodium content in the first and third stage. Na_2P_1 is significant in first season which has got a value of $.5 \times 10^{-4}$. During the third stage of growth $Na_0 P_2$, $Na_1 P_0$ and $Na_1 P_2$ are on par giving a value of 1×10^{-4} each. These are significant over all other treatments.

When water treatments are given there is a positive correlation with soil moisture and soil sodium giving an r-value of 0.37. During the first stage of growth also there is a positive correlation obtained (34%). This result is in confirmity with the work of Devitt et al. (1984) that the ability of a root system to tolerate high levels of soluble salt and in particular high levels of sodium is partially due to compensatory uptake of water and ions in the most favourable regions. At the lower water level the sodium content in the soil is found to be higher. Generally higher dose of phosphorus has a tendancy to increase exchangeable sodium in soil Smillie et al., (1987) have noted that a high proportion (80%) of the added phosphorus could be recovered by water extraction when exchangeable calcium was replaced by sodium.

4.4.7. Total nitrogen, phosphorus and potassium

The pooled samples collected at a depth of 15 cm at the third stage for different treatments are analysed for total nitrogen, phosphorus and potassium by digestion method. No statistical analysis is done for these values. But mean values are presented in table 38.

Within the different levels of phosphorus and sodium total nitrogen content is found to decrease with the increase from P_0 to P_2 and Na_0 to Na_2. Two water levels do not make much difference.

Considering total phosphorus in the soil for final analysis of phosphorus at a level of 90 g/plant and 115 g/plant gives the higher value of total phosphorus in the soil. As the sodium level increased total phosphorus decrease from .0216 to .0203. Water at 20 per cent depletion from field capacity give a higher value of phosphorus (.0214).

Table-38 Effect of different levels of Na, P, Water and their interaction on soil total nitrogen, total Phosphorus and total potassium (%)

Treatments	Total nitrogen	Total phosphorus	Total potassium
W1 P0 Na0	.2074	.0356	.0692
W1 P0 Na1	.0719	.0092	.0111
W1 P0 Na2	.0494	.0105	.0079
W1 P1 Na0	.1021	.0142	.0046
W1 P1 Na1	.0571	.0509	.0017
W1 P1 Na2	.0401	.0188	.0007
W1 P2 Na0	.0852	.0271	.0041
W1 P2 Na1	.0402	.0071	.0029
W1 P2 Na2	.0288	.0196	.0005
W2 P0 Na0	.1137	.0194	.0036
W2 P0 Na1	.0760	.0161	.0027
W2 P0 Na2	.0557	.0229	.0011
W2 P1 Na0	.1047	.0183	.0048
W2 P1 Na1	.0597	.0199	.0034
W2 P1 Na2	.0357	.0259	.0039
W2 P2 Na0	.0779	.0148	.0046
W2 P2 Na1	.0406	.0243	.0023
W2 P2 Na2	.0346	.0239	.0018
Mean value for			
P0	.0957	.0189	.0187
P1	.0666	.0247	.0032
P2	.0512	.0195	.0027
Na0	.1152	.0216	.0152
Na1	.0576	.0212	.0040
Na2	.0407	.0203	.0027
W1	.0758	.0214	.0114
W2	.0665	.0206	.0031

Total potassium content in soil decreased with levels of phosphorus and sodium. Among the treatments maximum value is obtained for $W_1P_0Na_0$ (.0692) and minimum value is for $W_1P_2Na_2$ (.0005). For the higher water level total potassium content (.0114) is higher than at lower water content (.0031).

Wherever the total content of soil nitrogen, phosphorus and potassium increase, the availability of each of these element found to decrease in the soil. The available nitrogen and potassium is high at higher levels of phosphorus, while total nitrogen and potassium are high at lowest level of phosphorus. An increase in total CEC by the addition of super phosphate has been reported by Gillman and Fox (1980). They have reported that the leaching of applied nutrients calcium, magnesium and potassium was retarded and greater quantities of these cations are present in the 0-50 cm protile than in the plot receiving no phosphorus.

In the case of different levels of sodium also, an increase in sodium decrease total nitrogen and potassium, but increase available nitrogen and potassium. Thus sodium is also found to have a role in releasing nitrogen and potassium. Being a monovalent, potassium in the exchange site of the complex might have been replaced by same valent sodium there by releasing it. This result is also in conformity with the work of Devitt et al., (1981) that increasing the salinity of the irrigation water increased the concentration of both sodium and potassium in the saturation extracts.

From the data for total nutrient content of soil more release of nutrients are occured in the lower levels of water applied. Release of phosphorus also is more from higher doses of sodium and lower levels of water content. Thus sodium at the rate of 136 g/plant/annum has increased availability of all the nutrients. Gupta et al. (1985) from their experiment observed that at 29.3 ESP, diammonium phosphate was a better source of phosphorus than monocalcium phosphate but at 59.2 ESP monocalcium phosphate outyielded diammonium phosphate. The higher sodium percentage would have increased the availability of phosphate from monocalcium phosphate. Russelle et al., (1981) showed that maximum fertilizer use efficiency was obtained with the low rate of water applied on a side dressing and with light frequent irrigation. This result agrees with the present finding that lower water level increased the total nutrient content in the soil.

4.4.8. Plant analysis

Plant nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and sodium are analysed during the final stage of the experiment and data are statistically analysed and mean values are presented in tables 39 to 42.

Table-39 Effect of different levels of P, Na, Water and their interactions in plant N, P and K

Sources	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	1.6940	1.8490	1.2407	0.0274	0.0340	0.0348	.9250	.8769	.8280
W2	1.9569	1.5382	1.7158	0.0300	0.0303	0.0313	.8368	.9704	.9391
Na0	1.9417	2.0712	1.4450	0.0261	0.0322	0.0316	.7605	.7783	.5838
Na1	1.9423	1.5203	1.4613	0.0335	0.0320	0.0319	.9742	1.0307	.9383
Na2	1.5923	1.4893	1.5283	0.0266	0.0322	0.0357	.9092	.9620	1.1285
Mean for Phosphorus	1.8255	1.6936	1.4783	0.0287	0.0321	0.0331	.8313	.9237	.8836
CD at 5% level for Phosphorus	-	0.4871	-	-	0.0049	-	-	.1243	-
CD at 5% level for WxP	-	0.6089	-	-	0.0069	-	-	.1758	-
CD at 5% level for PxNa	-	0.8437	-	-	0.0085	-	-	.2153	-

Table-40 Effect of different levels of Na, Water and their interactions on plant N, P and K

	Plant nitrogen (%)			Plant phosphorus (%)			Plant potassium (%)		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	1.8301	1.5336	1.4200	.0322	.0302	.0338	.6756	0.9600	0.9951
W2	1.8084	1.7491	1.6533	.0277	.0347	.0292	.7396	1.0021	1.0047
Mean for Sodium	1.8193	1.6413	1.5367	.0300	.0325	.0315	.7076	0.9811	0.9999
Mean for Water W1	-	1.5946	-	-	.0321	-	-	0.8760	-
W2	-	1.7370	-	-	.0305	-	-	0.9154	-
CD at 5% level for Water	-	0.3077	-	-	.00403	-	-	0.1015	-
CD at 5% level for Sodium	-	0.4871	-	-	.00493	-	-	0.1243	-
CD at 5% level for WxNa	-	0.6889	-	-	.00697	-	-	0.1758	-

Only plant phosphorus and plant potassium has been affeceed by interaction effect of water and sodium. Total phosphorus range from 0.0277 (W_2Na_0) to 0.0347 (W_2Na_1). Lowest water level with highest level of sodium has influenced plant uptake of potassium (1.0347). Lower values of plant uptake of potassium is obtained for lower levels of sodium in both the water levels.

Nitrogen uptake by plant is not much influenced by any of the treatments. Available nitrogen and plant uptake of nitrogen is related (Table No. 26 and 27 and Table No. 39) where, for highest dose of phosphorus, highest uptake of phosphorus is observed. Higher water content has also increased uptake of phosphorus. The results of the work by Reddy and Shastry (1983) showed that the crop uptake of phosphorus and potassium was greately facilitated at irrigation water/cumilative Pan evaporation (IW/CPE) ratio of 1.05. The total phosphorus plant content at higher level of water in the present study agrees with this finding.

Higher dose of sodium irrespective of water level has increased potassium uptake of plant. Since sodium helped release of potassium thereby increasing the plant uptake of potassium. With no sodium and minimised water, plant potassium is reduced. Even at lower levels of water (W_2) sodium has helped in the uptake of potassium. Plant potassium in the leaves is an indicator of soil available potassium. The

Fig. 16. Effect of different levels of Na, P, Water and their interaction on nitrogen in plant during yielding stage.

Fig. 17 Effect of different levels of Na, P, Water and their interaction on phosphorus in plant during yielding stage.

Fig 16

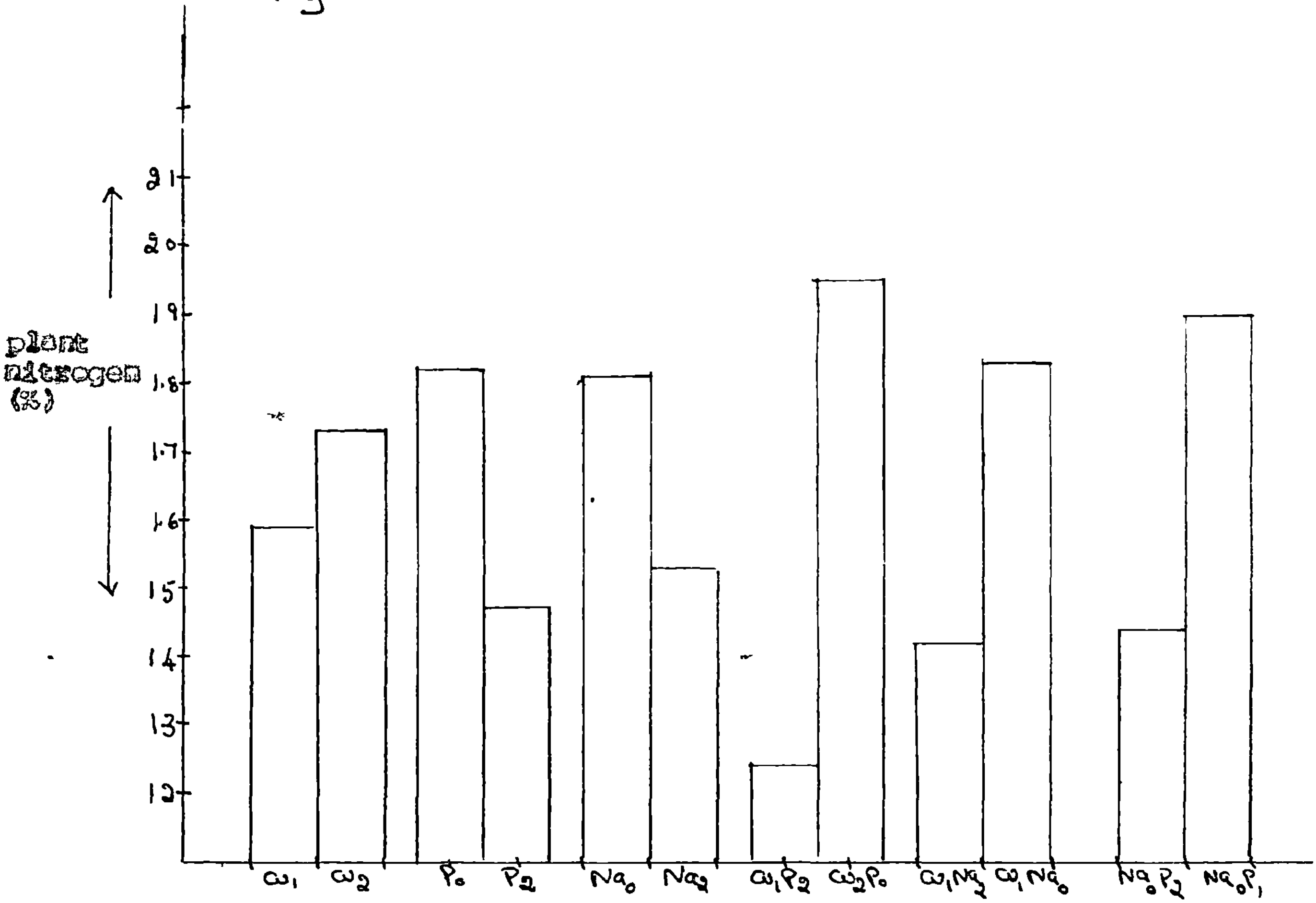
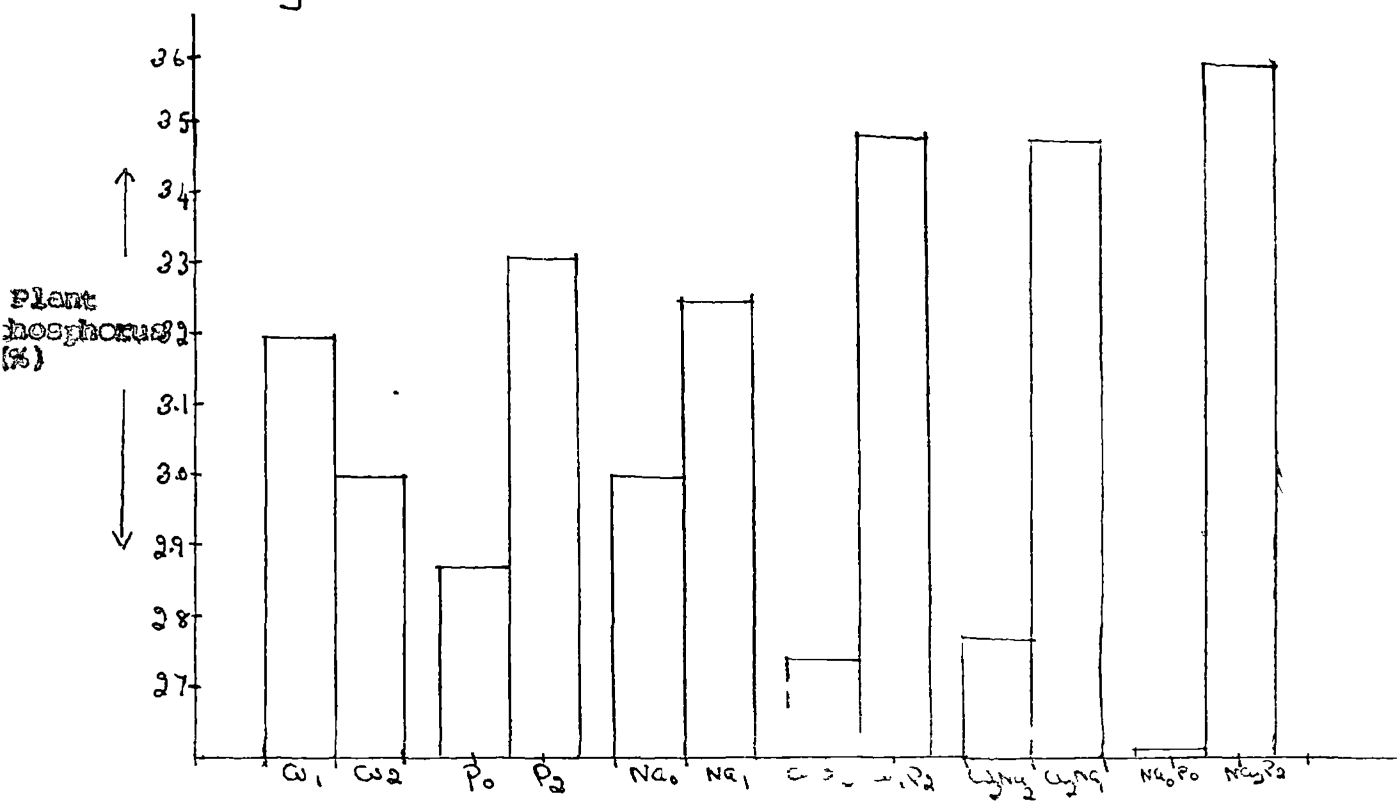

2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
plant nitrogen (%)
W1
W2
P0
P2
Na0
Na2
W1P2
W2P0
W1Na2
W1Na0
Na0P2
Na0P1

Fig 17


3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
Plant phosphorus (%)
W1
W2
P0
P2
Na0
Na1
W1Na2
W2Na1
Na0P0
Na2P2

available potassium in the soil is increased at the medium dose of sodium as the level increased from Na_3 to Na_1 (Table 30 and 31). The available potassium in the soil is reflected in the plant potassium at higher levels of sodium treatment. Devitt et al., (1981) worked out a potassium/sodium ratio in the leaves at the harvest time and this ratio is found to be very much related to the product of potassium/sodium in soil solution and the root length density. In the present result also the higher root density in the lower water levels would have encouraged the uptake of potassium by the plant roots.

A positive correlation is observed for plant uptake of phosphorus and mycorrhizal population. Plant phosphorus is positively correlated with mycorrhizal population (45%), soil sodium (26%), soil phosphorus (35%) and mean weight diameter (39%) table No.45 (Correlation matrix). The results given by Omusu and Wild (1980) supports the present correlation. They found that inoculation of lettuce, onion and clover with vesicular arbuscular mycorrhizal fungus (Glomus mosseae) increased plant yields and phosphate uptake in three soils that had been depleted in phosphate. The lower specific activity in lettuce and clover has been attributed to greater release of slowly exchanging phosphate caused by the high uptake of phosphate by the mycorrhizal plants.

Westerman et al., (1984) found increased uptake of nitrogen, phosphorus and potassium when phosphorus is applied.

Mean while only the phosphorus and potassium uptake is influenced by increased levels of phosphorus, in this study.

4.3.8.2. Plant calcium, magnesium and sodium

Using the same extract, calcium, magnesium and sodium in the plant leaves are analysed using atomic absorption spectrometer during last stages of experiment. Mean values are presented in Table No. 41 and 42 and Figure in 19 and 20.

Individual effect of water and sodium are not significant in the plant uptake of calcium, magnesium and sodium. Different levels of phosphorus have significant effect on all the three elements. For the uptake of calcium and magnesium maximum dose of phosphorus gives highest value of 0.3474 (Ca), and 0.1862 (Mg). Phosphorus at the rate of P_1 increased the sodium content of plant. (.2571).

In the interaction effect also higher levels of water with the highest dose of phosphorus has given maximum uptake of calcium (.4034) and magnesium (.1956). This treatment is found to be significant over W_1P_1 in both cases, giving a minimum values of .1517 for calcium and .1250 for magnesium. In the case of sodium uptake, W_1P_1 is found to be superior and giving a value of 0.2818.

Higher values of plant calcium and magnesium are also observed for a combination of higher dose of sodium and higher dose of phosphorus. Na_1P_2 gives a value of 0.4048 for plant

Table-41 Effect of different levels of Na, P, Water and their interactions for Calcium, magnesium and sodium in banana leaves

	Calcium (%)			Magnesium (%)			Sodium (%)		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
W1	.2257	.1517	.4034	.1663	.1250	.1956	.2200	.2818	.1718
W2	.2769	.2804	.2913	.1752	.1692	.1767	.2020	.2323	.2109
Na0	.3292	.0857	.2898	.1984	.1220	.1653	.1542	.3652	.1570
Na1	.2240	.2957	.4048	.1525	.1611	.1966	.1972	.1800	.2105
Na2	.2007	.2668	.3475	.1614	.1583	.1966	.2817	.2260	.2065
Mean for Pot Phosphorus	.2513	.2161	.3474	.1708	.1471	.1862	.2110	.2571	.1914
CD at 5% level for Phosphorus	-	.1109	-	-	.0383	-	-	.0577	-
CD at 5% level for WxP	-	.1569	-	-	.0541	-	-	.0816	-
CD at 5% level for PxNa	-	.1922	-	-	.0663	-	-	.0999	-

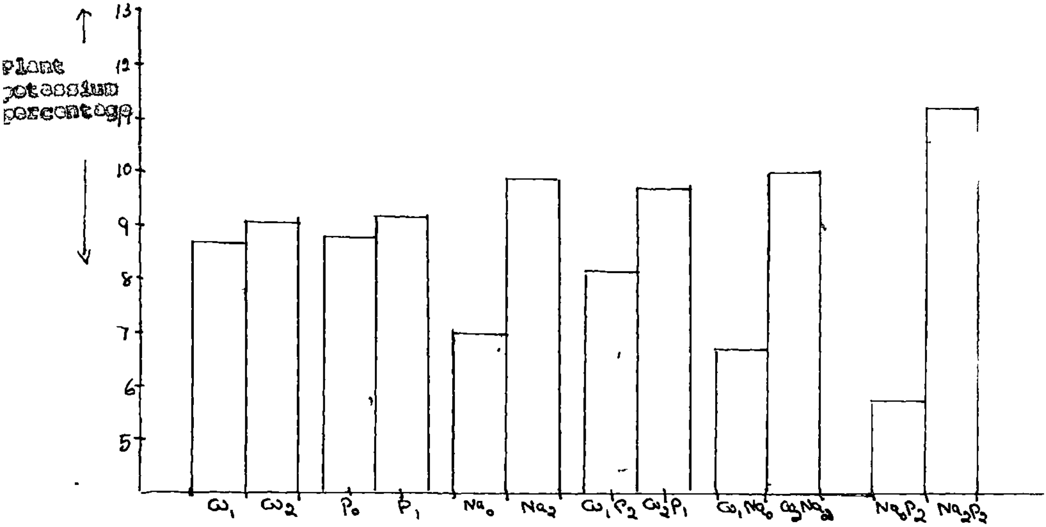
Table-42 Effect of different levels of Na, Water and their interactions on plant Ca, Mg and Na

	Calcium (%)			Magnesium (%)			Sodium (%)		
	Na0	Na1	Na2	Na0	Na1	Na2	Na0	Na1	Na2
W1	.1949	.3521	.2338	.1429	.1917	.1523	.2753	.1742	.2240
W2	.2749	.2642	.3096	.1809	.1484	.1919	.1756	.2176	.2591
Mean for Sodium	.2349	.3082	.2717	.1619	.1700	.1721	.2254	.1959	.2381
Mean for Water W1	-	.2603	-	-	.1623	-	-	.2245	-
W2	-	.2829	-	-	.1737	-	-	.2151	-
CD at 5% level for Water	-	.0906	-	-	.0313	-	-	.0471	-
CD at 5% level for Sodium	-	.1109	-	-	.0383	-	-	.0577	-
CD at 5% level for WxNa	-	.1569	-	-	.0541	-	-	.0861	-

Fig. 18 Effect of different levels of Na, P, Water and their interaction on plant potassium during the yielding stage.

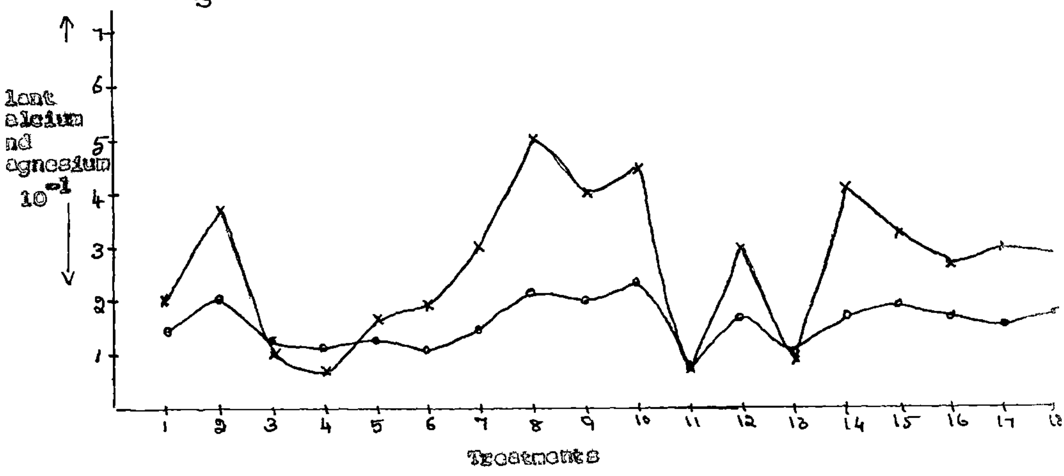
Fig. 19 Effect of different levels of Na, P, Water and their interaction on plant calcium and plant magnesium during the yielding stage.

Fig. 18



plant
potassium
percentage
13
12
11
10
9
8
7
6
5
Co_1
Co_2
P_0
P_1
Na_0
Na_2
Co_1P_2
Co_2P_1
Co_1Na_0
Co_2Na_2
Na_0P_2
Na_2P_2

Fig 19



lant
alcium
nd
agnesium
10^{-1}
7
6
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4
3
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16
17
Treatments

calcium and 0.1966 for plant magnesium. Sodium in plant is found to be on par for Na_2P_0 (.2817) and Na_0P_1 (.3652). Minimum value of plant sodium is obtained for no sodium, with no phosphorus treatment.

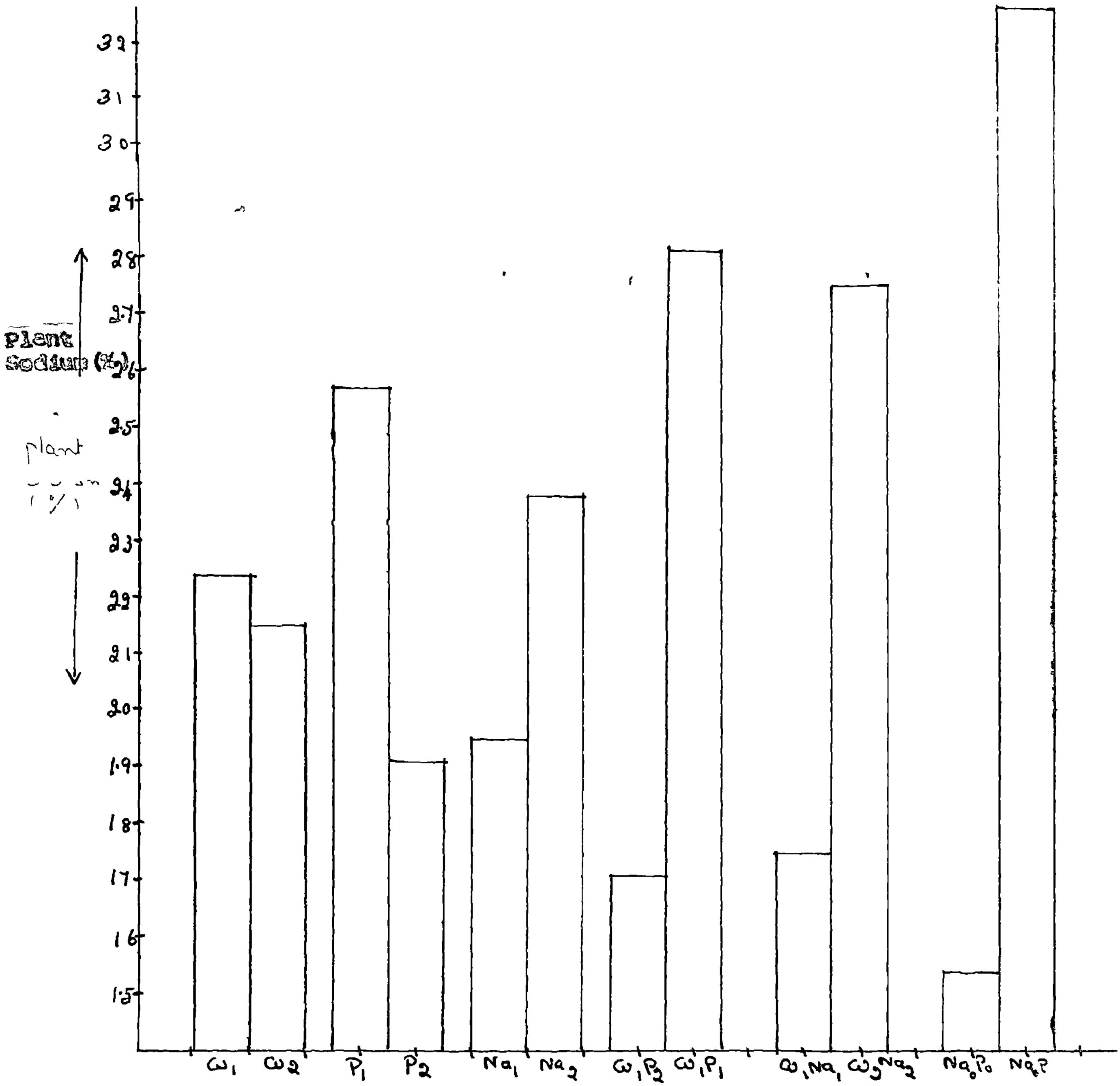
Treatment combination of W_1Na_1 has given higher values of plant calcium (.3521) and plant magnesium (.1917). In case of calcium this value is significant over other but for magnesium in plant no significance is observed. For the combination of sodium and water, the plant sodium ranged from 0.1742 (W_1Na_1) to 0.2753 (W_1Na_0). W_1Na_0 is on par with W_2Na_2 (.2591).

The effects of different treatments almost similar in case of plant content of calcium and magnesium both being divalent cations. When there is no phosphorus application, effective uptake of these cations are prevented to some extent.

At lower water level uptake of calcium and magnesium can be increased with an optimum dose of sodium in the soil. This is evident from the tables for available calcium (Table No. 32 and 33) and available magnesium (Table No. 34 and 35) which is also increased at an optimum level of sodium. Patel and Ghildyal (1983) from their experiment came to the conclusion that the inflow rate of nutrients was the maximum under unsaturated treatments and was higher with drainage treatments, than under flooding and under recycling treatments. At lower water levels

Fig. 20. Effect of different levels of Na, P, Water and their interaction on plant sodium during the yield stage.

Fig 20



Plant Sodium (%)
plant
(%)
3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
W1
W2
P1
P2
Na1
Na2
W1P2
W1P1
W1Na1
W2Na2
NaoPo
Na1P

the inflow of calcium and magnesium might have increased, to enhance their uptake by plants.

Plant sodium is positively correlated with available soil phosphorus, mycorrhizal population, plant phosphorus, and hydraulic conductivity of the soil (Table 45 and Fig.20).

From the results obtained it can be seen that the sodium at an optimum level can increase available calcium, phosphorus and magnesium to some extent. The work by Bladel and Cneyi (1980) reported that calcium was selectively adsorbed over sodium and to a lesser extent over magnesium. As the sodium level increased from Na_0 to Na_2 Nitrogen uptake is found to decrease insignificantly. Paliwal and Maliwal (1975) have statistically correlated the plant uptake of nitrogen and phosphorus with the salinity of soils.

Table-43 Correlation matrix for first stage

	Soil available Phosphorus	Moisture percentage	WHC	Soil sodium	Mean weight diameter
Moisture percentage	0.1968				
WHC	-0.0957	0.3489			
Soil sodium	0.0255	0.3390	0.4491		
Mean weight diameter	-0.1196	0.2092	-0.2180	0.1599	
Mycorrhizal percentage	0.2378	0.1116	-0.0129	-0.1839	0.0045

Table-44 Correlation matrix for second stage

	Soil available Phosphorus	Moisture percentage	WHC	Soil sodium	Mean weight diameter
Moisture percentage	0.3610				
WHC	-0.1819	-0.0709			
Soil sodium	-0.3753	-0.0606	-0.4010		
Mean weight diameter	0.0684	-0.1325	0.0973	-0.4235	
Mycorrhizal percentage	-0.2295	-0.1158	-0.1570	0.0258	-0.2265

Table-45 Correlation matrix for the third stage

	Soil sodium	Available phosphorus	Moisture percentage	WHC	MWD	Mycorrhizal percentage	Plant P	Plant sodium
Soil available Phosphorus	0.0302							
Moisture percentage	0.3761	-0.0684						
WHC	-0.2379	0.0143	0.0639					
MWD	-0.0707	0.1657	-0.0611	0.2311				
Mycorrhizal percentage	-0.3534	-0.2810	-0.1652	-0.0487	-0.2089			
Plant phosphorus	0.2566	0.3525	-0.1404	-0.3332	0.3939	0.4485		
Plant sodium	-0.3719	0.0391	-0.3636	0.0884	-0.1504	0.1337	0.1540	
Hydraulic conductivity	-0.0709	0.5286	0.0721	0.2451	0.0058	-0.2210	0.0461	0.3005

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

Present investigation is undertaken to study the influence of different levels of phosphorous, sodium and water on the plant characters of banana (var. Nendran) and on the physico-chemical and biological characteristics of soil. The experiment is laid out in randomised block design in the farm area of College of Agriculture, Vellayani. Three levels of phosphorous include, control, 90 kg and 115 g P_2O_5/plant/annum. The levels of sodium are control, 68 and 136 g of sodium/plant/annum. 20 and 40 per cent depletion from field capacity moisture content (7.34%) are the two water levels given. Preliminary analysis of soil samples are conducted for major nutrients and important physical properties. Biometric observations such as plant height, number of leaves, leaf area index and girth of pseudostem are recorded and analysed. Vesicular arbuscular mycorrhizal counting for three seasons are recorded.

Soils collected at 15 cm depth at 90 days, 180 days and 270 days (harvest stage) are analysed for various physical properties such as moisture content, bulk density, particle density, water holding capacity, volume of expansion, porosity and aggregation. The available nitrogen, phosphorous, potassium, organic carbon content, exchangeable calcium, magnesium and sodium are determined for these soil samples.

The plant uptake of nitrogen, phosphorous, potassium, calcium, magnesium and sodium are done using 3rd leaf collected from different replications, after the harvest. The hydraulic conductivity and total nutrient content such as nitrogen, phosphorous and potassium for the soil, analysis are done only for the samples collected at the final stage. The average rainfall relative humidity, atmospheric temperature during the period of crop growth are recorded and used for interpretation of mycorrhizal population. The analysis of variance for all these observations are done and the data are interpreted for various treatment effects. Important parameters are correlated and correlation matrix is presented. From the results obtained the following conclusions are drawn.

1. Plant height, number of leaves and leaf area index are not affected by the individual effects of water, phosphorous and sodium. Higher levels of sodium decrease girth of the pseudostem. Maximum level of phosphorous is found to be favourable for all these biometric observations especially during the final stage of growth. In the presence of sodium the effect of phosphorous is predominant. In the case of girth of the pseudostem sodium has an adverse effect, even at higher levels of phosphorous. When the water level has been reduced to 40 per cent depletion from field capacity in the presence of sodium and phosphorous high values for leaf area index are observed.

2. During the crop growth maximum mycorrhizal percentage recorded during the third season when the rainfall, relative humidity and atmospheric temperature are at the optimum. The different levels of sodium and phosphorous or their interaction do not affect the mycorrhizal population. The soil moisture and soil available phosphorous are negatively correlated with mycorrhizal percentage. But plant phosphorous and sodium are positively correlated with mycorrhizal population. Moisture at 40 per cent depletion from field capacity is sufficient for proper VAM growth. Even at lower levels of phosphorous applied its uptake by plant is influenced by mycorrhizal association.

3. The moisture percentage in the soil to some extent is increased in the presence of sodium, at the optimum level. At lower water content moisture retension has been influenced by sodium content there by the moisture percentage in these plots are found to be higher than the plots where more water is supplied.

4. Bulk density and particle density can be brought to an optimum level in the presence of sodium and phosphorous. Lower water levels also reduce bulk density and particle density to a favourable value. This has been reflected in the water holding capacity of soil. Higher levels of phosphorous and sodium increase water holding capacity.

5. Higher values for volume of expansion are recorded for maximum levels of phosphorous and sodium. Sodium in the exchange complex helps the expansion property. The proportion of macro and micro porosity is maintained, at an optimum dose of phosphorous and sodium along with lower levels of water.

6. Soil aggregation is evaluated using the single value of mean weight diameter. The percentage of aggregate more than 0.25 mm in diameter was correlated with mean weight diameter. As the mean weight diameter increases the gradation in aggregation decreases. The mean weight diameter is positively correlated with soil phosphorous and negatively correlated with soil moisture.

7. An optimum dose of phosphorous and sodium favourably influence hydraulic conductivity. Highest level of sodium interfere the hydraulic conductivity while no sodium treatment also reduce water movement by minimising soil aggregation.

8. The effect of treatments on organic carbon content and available nitrogen are negligible. But a trend in general, is seen that for an optimum dose of sodium and phosphorous there is increase in the organic carbon and soil available nitrogen. Lower level of water is found to be sufficient to increase soil nitrogen as well ~~as well~~ organic carbon content.

9. There is a positive correlation between soil available phosphorous and mycorrhizal percentage. Effect of sodium is not that prominant on available phosphorous. ~~The maximum available phosphorous.~~ The maximum available phosphorous is found during the second stage of growth. Water requirement is less for making the phosphorous available in the presence of sodium.

10. Available potassium in the soil is enhanced with optimum dose of sodium and maximum level of phosphorous. As the plant grows the available potassium in the soil decreases.

11. Maximum amount of exchangeable calcium magnesium and sodium observed with optimum dose of sodium and high level of phosphorous. Availability and uptake of these cations are favoured by higher levels of water content. There is a positive correlation exist between soil moisture and soil sodium.

12. Total nutrient content of nitrogen, phosphorous and potassium are decreased when the levels of sodium, phosphorous, and water are increased, thereby favouring the availability of these elements.

13. Plant nitrogen is not affected by soil phosphorous, mean while plant phosphorous is very much related with soil available phosphorous. But an optimum dose of phosphorous and lower level of water are necessary for optimum uptake of potassium. As the sodium level increased potassium availability

and uptake increased. Positive correlations are obtained for plant phosphorous with mycorrhiza, soil sodium, soil phosphorous and mean weight diameter.

14. Uptake of calcium and magnesium responded almost similarly to different treatments. Highest levels of phosphorous and water and medium level of sodium favour calcium and magnesium uptake. While an optimum level of phosphorous increases sodium uptake. In the presence of sodium even at lower water level calcium and magnesium uptake is increased. Plant sodium is positively correlated with soil available phosphorous, mycorrhizal population, plant phosphorous and hydraulic conductivity.

The presence of an optimum level of sodium in the soil improve the hydraulic characteristics of soil. The mycorrhizal population is found to help the phosphorous uptake indicating that lower level of phosphorous will be sufficient to meet the requirement of the plant in their presence. Sodium and phosphorous at a medium dose may improve the soil conditions in relation to plant growth. Different combinations of sodium phosphorous and water can be further studied to obtain more affirmative conclusions.

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INFLUENCE OF WATER AND SPECIFIC ANIONS AND CATIONS ON PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL

BY

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ABSTRACT OF A THESIS

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ABSTRACT

The availability of nutrients either present in the soil or applied as fertilizer is governed by various factors like the physical, chemical and biological reactions in the soil. The present investigation is undertaken to study the direct and interaction effects of different levels of phosphorous, sodium and water on the physico-chemical and biological properties of soil.

An experiment is laid out in the farm area of College of Agriculture, Vellayani. The lay out is in randomised block design with 18 treatments and three replications. Banana var. Nendran is used as the test crop. The treatment combinations include, three levels of phosphorous (control, 90 and 115 g P_2O_5/plant/annum), three levels of sodium (control, 68 and 136 g Na/plant/annum) and two levels of water (20 and 40 per cent depletion from field capacity moisture condition). Soil and plant analysis are done for the elements, nitrogen, phosphorous, potassium, calcium, magnesium and sodium. Initial soil samples and samples collected at 90, 180 and 270 days after planting are used for different physico-chemical analysis. Physical properties such as moisture parameter, bulk density, particle density, porosity, water holding capacity, volume of expansion and aggregation are done for all the soil samples. Total nutrient contents and hydraulic conductivity for the

soil samples collected at the final stage are also done. Plant samples collected at the harvest are analysed for total nitrogen, phosphorous, potassium, calcium, magnesium and sodium. Biometric parameters such as plant height, number of leaves, girth of pseudostem and leaf area index are observed and recorded during three stages. Mycorrhizal counting is carried out, during all the stages, considering as three seasons. All the data are statistically analysed and interpreted.

Phosphorous at the highest dose is beneficial for all the biometric parameters studied. In the case of sodium, it has an adverse effect on the girth of the pseudostem, even at the highest level of phosphorous. Leaf area index is very high in the presence of sodium and phosphorous even at 40 per cent depletion from field capacity. Soil phosphorous and soil moisture are negatively correlated with mycorrhizal percentage during second and third stage. Plant phosphorous and sodium positively correlated with the mycorrhizal percentage. Even with moisture at 40 per cent depletion from field capacity and lower amounts of phosphorous applied, the uptake of phosphorous by the plant is increased by mycorrhizal association.

Higher levels of phosphorous and sodium increase the waterholding capacity and volume of expansion. Bulk density and particle density give optimum values with medium levels of phosphorous and sodium. Moisture percentage increased in plots with optimum sodium than with plots receiving higher dose of water with no sodium. Lower water level reduces bulk density and particle density. The mean weight diameter which is a measure of soil aggregation is positively correlated with soil phosphorous and negatively correlated with soil moisture. Optimum dose of phosphorous and sodium favour hydraulic conductivity of soil.

Medium dose of sodium and phosphorous increase organic carbon and soil available nitrogen. Lower level of water is sufficient for increasing soil available nitrogen, soil available phosphorous and organic carbon, in the presence of sodium. Positive correlation exists between soil available phosphorous and mycorrhizal percentage in the first stage. Maximum phosphorous is available during the second stage with a negative correlation with mycorrhiza. Optimum dose of sodium and high level of phosphorous, increase the availability of available potassium, exchangeable calcium, and exchangeable magnesium. There is a positive correlation exist between soil moisture and soil sodium. As the plant grows the soil available potassium decrease. Higher levels of water, increase, exchangeable calcium and magnesium also. Total nutrient content of nitrogen, phosphorous and potassium are decreased with increasing phosphorous, sodium and water, which is, because of their increased availability. Plant phosphorous is related with soil available phosphorous. For optimum dose of phosphorous, lower level of water and higher level of sodium, the availability and uptake of potassium is at the optimum. Positive correlation obtained for plant phosphorous with mycorrhiza, soil sodium, soil available phosphorous, and mean weight diameter. Plant sodium is also positively correlated with soil available phosphorous, mycorrhizal population, plant phosphorous and hydraulic conductivity. Highest level of phosphorous and water and medium level of sodium favour the uptake of calcium and magnesium. For increasing sodium availability, only optimum dose of phosphorous is required.

Sodium at the optimum dose improve soil hydraulic properties. Optimum dose of phosphorous and sodium improves many of the physico-chemical properties of the soil. In the presence of mycorrhiza, even lower levels of phosphorous is sufficient to meet the plant requirement. With more levels of phosphorous, sodium and water, the study can extended in relation to plant growth. Yield factor is not considered in the present study.