

# STUDIES ON THE GROWTH OF SOYBEAN IN RELATION TO SOIL MOISTURE AND NITROGEN STRESS IN A BLACK CLAY SOIL

## THESIS

Submitted to the

**Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur**

in partial fulfilment of the requirements for  
the Degree of

**MASTER OF SCIENCE**

**IN**

**AGRICULTURE**

( SOIL SCIENCE AND AGRICULTURAL CHEMISTRY )

BY

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**1985**

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Dedicated to the memory of my uncle

Late Shri KRISHNA KUMAR JI DIXIT

whose silent presence has guided my efforts.

CERTIFICATE - I

This is to certify that the thesis entitled "STUDIES ON THE GROWTH OF SOYBEAN IN RELATION TO SOIL MOISTURE AND NITROGEN STRESS IN A BLACK CLAY SOIL" submitted in partial fulfilment of the requirements for the degree of "Master of Science in Agriculture" of the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by SHRI BRIJESH KUMAR DIXIT, I.D.No.138/78 under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of this thesis has been submitted for any other degree or diploma, certificate awarded etc., or has been published/published part has been fully acknowledged. All the assistance and help received during the course of investigation have been duly acknowledged by him.

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### ACKNOWLEDGEMENT

I, Brijesh Dixit, praise the immortal, omniscient and omnipotent Lord Sri Krishna, who gave me this opportunity of doing M.Sc.(Ag.).

It is my great pleasure to express, even though words may fail, my immense esteemed gratitude to Dr. R.A.Sharma, Soil Physicist, Dryland Agriculture Research Project, College of Agriculture, Indore, whose able guidance, unceasing enthusiasm and encouragement, genuine criticism<sup>ci</sup> coupled with plentiful help during the course of this investigation was a constant source of great inspiration to me.

I have immense pleasure in expressing my heartfelt gratitude to Dr. G.P.Verma, Dean, College of Agriculture, Indore, for providing me necessary facilities during the course of my study.

With the deepest sense of humanity and gratefulness, I feel myself duty bound to express my sincere thanks to the members of my Advisory Committee, Dr. R.K.Gupta, Chief Scientist, Salt Affected Soils Project, Dr.D.A.Shinde, Professor and Head of the Section of Soil Science and Agricultural Chemistry, Shri D.P.Gupta, Assistant Professor of Food Science and Shri G.L.Patidar, Assistant Professor of Mathematics and Statistics, for their unfailing kind help and suggestions, during the period of investigation.

My sincere thanks goes to the staff members of the Department of Soil Science, Salts Affected Soils and Dryland

Agriculture Project, S/S N.K.Sharma, B.S.Solanki, J.M.Dighe, B.G.Iyer, Dr.O.P.Sharma, Dr. D.D.Dubey, V.K.Khadger, V.Thukaral, and S.K. Upadhyay, Assistant Professors; C.K.Pathak, Maikulal, Munshi Khan, Nimbbi Singh and Uttam Ingle Lab. Assistants for their cooperation during this investigation.

I express my most affable and cordial thanks to my colleagues and friends S/S The great Arun Rawat, V.B.Mishra, J.K.Sharma, S.R.S.Patel, S.S.Sengar, N.R.Badkur, D.K.Rai, D.K.Dandir, A.K.Selot, V.S.Tomar, C.Singh, R.K.Gupta, R.S.Rathore, S.K.Yadav, A.K.Joshi and O.P.Patidar for immense help provided by them from time to time.

Words fail to express my indebtedness to my grand parents Pt. Shri Radheshyamji Dixit and Smt. Phoola Bai Dixit, beloved parents Shri Prahlad Kumarji Dixit, and Smt. Vimala Dixit; uncles Sarva Shri V.P.Dixit, M.P.Dixit, D.P.Mahere, R.K.Sharma, V.K.Shukla, S.K.Shukla, M.L.Dubey and J.P.Tiwari, motherly aunts S/Smt. Rameti Mahere, Sarla Sharma, and Shashi Shukla, whose affectionate assistance, firm ambition evergreen blessings, accompanied with encouragement have brought me to present level and made my present endeavour possible.

At last but not the least I express my humble gratitude to my elder brothers Shri Kamlesh Dixit and Shri Gajendra Mahere, brother-in-law Shri Raj Kumar Arele, sister Smt. Yashodhara Arele, Ku. Danyanti, Ku. Pushplata, Ku. Sushma and Ku. Somlata Dixit and brothers Bhanu, Rakesh, Rajesh, Sushil, Lalit, Sunil, Subhodh and Sudhir Dixit.

INDORE

  
( BRJESH DIXIT )

DATED : 30 Sept. 1985

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INTRODUCTION

## INTRODUCTION

Soybean can be a finest vegetative protein source not only of Madhya Pradesh but also of India. The protein intake, particularly of high biological value, is very low in our country resulting malnutrition. Soybean which supplies both high quality fat and protein seems to solve the protein problem partly. Soybean contains around 40% protein and about 20% edible oil. This is very encouraging in fulfilling the needs of majority of vegetarian Indian population.

In Madhya Pradesh during the year 1982-83 the approximate acreage under this crop was 8.1 lakh hectares giving a total yield of 614 thousand tonnes with black soybean (70%) and improved yellow soybean varieties (30%). It occupied a premier position in production, contributing about 80 per cent of the national production of soybean. However, the per hectare yield (7.5 q/ha) is lowest in the world. Hence, to improve the per hectare yield and quality of soybean, it is essential to feed the crop properly.

It requires, like other legumes, a small dose of nitrogen to give a good start to the crop and the large quantities of phosphorus, sulphur, potassium and calcium, as otherwise, the crop removes relatively large amounts of these nutrients from the soil. Deficiency of any one of these nutrients leads to unsatisfactory soybean production. Nitrogen

is a limiting factor in the protein and oil yield. Expansion of industrial uses of soybean has stimulated research on composition of the seed, particularly in respect of oil and protein content. As a consequence the variability of composition has assumed importance particularly with respect of different new varieties.

Soybean oil has many medicinal uses. It is used in the cure of cancer, coronary diseases, diarrhoea, skin troubles. Soybean Lecithin being one of the strongest emulsifying agent is used commercially in many non-food uses e.g. textile, leather goods, soaps and detergents, cosmetics and fungicide preparations and as semidrying oil in paints and varnishes. It is also used in manufacturing many nutritive products e.g. margarine, mallowine etc.

Soybean is a crop suitable for temperate regions with fairly humid, warm growing season. In comparison to other leguminous crops, it is less sensitive to frost, drought and wet weather. It succeeds on a wide variety of soils and can thrive well in acid soils or soils low in calcium content (Wolf & Kipps, 1959).

Water stress is another important factor which affects practically every aspect of plant growth right from emergence to seed formation, modifying the anatomy, morphology, physiology and biochemistry. Low soil water potential is the most limiting factor for germination and establishment of crops. Many times a proper plant stand is not achieved

due to failure of seed germination, which is usually due to poor water availability to seed. Under restricted water absorption, seed may take more time to emerge and the emergence may lack uniformity. Sometimes, after successful emergence, crop may face soil moisture stress of varying degrees during vegetative growth period and ultimately retard the yields. Soil water and plant relationship has been the subject of a great deal of research yet very little information in this regard is available for soybean grown on a black clay soil.

Therefore present studies were undertaken with the following objectives :

- (1) To evaluate and assess the influence of different degrees of soil moisture stress on seedling emergence, radicle and plumule growth of soybean.
- (2) To study the influence of varying soil water potential on growth of soybean.
- (3) To study the effect of varying soil water potential on transpiration of soybean.
- (4) To study the influence of different levels of nitrogen applied through urea, FYM and their combinations, on growth and yield of soybean.
- (5) To study the uptake of NPK, Ca and Mg as influenced by different levels and source of nitrogen.

- (6) To study the effect of different levels and source of nitrogen on oil and protein contents of soybean grain and their mutual relationships.
- (7) Changes in NPK, Ca and Mg in soil as affected by different treatments.

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**REVIEW OF LITERATURE**

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## REVIEW OF LITERATURE

Considerable work has been done on the soil-water and plant relationship and nitrogen fertilization in India and abroad. A brief review of the work carried so far relating to the influence of soil moisture stress on seedling emergence, transpiration, leaf water potential and other growth parameters of plants has been presented in this chapter. A brief resume of research work on the effect of nitrogen on yield and chemical composition of soybean grain and their interrelationships has also been given.

### 2.1 SEEDLING EMERGENCE

#### 2.1.1 Moisture absorption by seeds as influenced by water potential

The water availability is one of the most important factors controlling seed germination and plant establishment. Detmer (1898) found that the capacity for absorbing water is different for different kinds of seeds. He observed that peas absorbed 100 per cent of their air dry weight and wheat only 40 to 60 per cent. Stiles (1948, 1949) reported that all seeds do not require same amounts of water for germination. He further reported that various bean seeds differ in the total amount of water absorbed and in the rate of absorption. Hunter and Erickson (1952) observed that in order for the seeds to germinate each species had to attain specific moisture content. This minimum moisture was found

approximately 30.5 per cent for corn, 26.5 per cent for rice, 50 per cent for soybean and 31 per cent for sugarbeet.

Richard and Wadleigh (1952) stated that the osmotic and matric forms of soil water potential do affect the seeds water uptake and response to some extent.

Collis-George and Sands (1959) reported that both water absorption characteristics of seed and soil water influence the seed germination. Momota (1967) observed that under restricted water absorption, seed may take larger time for germination and seedling may lack uniformity.

Phillips (1968) found that diffusivity of soybean seed germinating in aerated distilled water was approximately 4 times larger than corn seed and approximately 18 times larger than for cotton seeds. The diffusivity of soybean and corn seed germinating in silt loam soil at four moisture content ranging from wilting percentage to field capacity was approximately equal at each soil moisture content. The diffusivity of each seed increased as soil moisture content increased.

Hadas (1970) observed no difference in water uptake by the seeds in each soil water potential inspite of the considerable differences between their hydraulic conductivities. Khan and Varade (1976) observed the water diffusivity of germinating legumenous spherical seeds of

gram, redgram and pea seeds in lateritic sandy clay loam soil at varying moisture content and in aerated distilled water in germinator at constant temperature. Water diffusivity of each type of seed at three moisture contents (7, 10 and 20%) increased with increasing time after planting the seed in soil. Water diffusivity of each seed germinated in aerated distilled water was approximately four times more than that in soil. They also concluded that the rate of movement of water in soil controls the absorption of water by seed and in turn, the seed water diffusivity.

Mensah et al. (1979) measured moisture isotherms separately for soybean seed coat and cotyledons showed that the seed coat equilibrated was also higher for the seed coat. Moisture diffusivities determinate from seed coat and cotyledons dry data, showed that seed coat resistance to moisture transfer was 6 times that of the cotyledons.

Woodstock and Tao (1980) stated that deterioration in soybean seeds apparently involved, at least in part, a decrease in ability of seed axes to tolerate water uptake at the short imbibition. This weakness may be compensated by osmotic control of water uptake.

#### 2.1.2 Effect of soil water potential on seedling emergence

The influence of soil water potential on percentage emergence of various crop seeds has been studied by many

workers under laboratory conditions. Their common conclusion is that the total rate of germination as well as total germination are decreased as matric potential decreases.

Ayers and Haywards (1948) stated that soil salinity impedes the rate at which seeds germinate and also decreases the number of seeds that do germinate. Hunter and Erickson (1952) observed that at 20°C a soil should have a moisture tension of not more than 12.5 atmosphere for corn and kernels to germinate, 6.6 atmosphere for soybean to germinate and 3.5 atmosphere for segmented sugarbeet seeds to germinate.

Gingrich and Russell (1956) observed that a decrease in matric potential affects seed or radicle behaviour to a larger extent than an equivalent decrease of the osmotic potential because of the simultaneous change in the capillary conductivity.

Collis-George and Sands (1962) found that the osmotic potential does not restrict germination unless high concentration is reached.

Collis-George and sand (1962); Collis-George and Hectar (1966) showed that when soil water potential was controlled by matric potential, germination was retarded at very small reduction in water potential.

Todnar and Hillel (1965) found that maximum germination of seeded dryland range under semi-arid

conditions required moisture conditions near field capacity. A moisture content  $2/3$  to  $3/4$  of field capacity severely reduced germination which was zero at 15 bars.

Jensen (1971) reported that the changes in tension from  $1/3$  to 1 bar has no significant effect on the time required for emergence and the growth rate of cotton seedlings in silt loam soil packed at  $1.10 \text{ g/cm}^3$ . The rate of emergence and growth rate progressively decreased as tension increased from 2 to 4 bars. Thereafter as tension increased, time required for emergence increased rapidly and rate of growth simultaneously decreased sharply. Emergence did not take place at tension greater than 12 bars.

Rao and Gupta (1976) reported that the rate as well as percentage seedling emergence of soybean were maximum at the suction of 0.3 bar although satisfactory emergence (greater than 70 per cent) occurred upto 3 bars suction when the depth of sowing was within 3 cm. They observed that the percentage emergence of soybean sown at different depths decreased and the time required to reach maximum emergence increased with the increase in moisture suction.

Sokolova and Khvan (1977) studied in field trial with soybean excessive moisture in the soil from emergence or from the pod formation stage onward decreased the proportion of asperic acid and glutamic acids and lysine in the seed CP.

Naik et al. (1978) found that the soybean seedling raised from seeds treated with different chemicals were subjected to drought. The values for drought tolerance parameters such as relative water content, free proline content and root weight were the highest with seed treatment 100 ppm cycocel sol followed by seed treatment in 0.2% zinc sulphate, 200 ppm ascorbic acid, water and untreated seed. The values for shoot weight and leaf area were the highest with seed treatment in water, intermediate with seed treatment in different chemicals and lowest with untreated seeds.

Heatherly and Russell (1979) evaluated the effect of different levels of soil water potential (SWP) on the rate and percentage of emergence of the soybean cv. Tracy from Sharkey clay and Dubbs silt loams equilibrated to soil water potential of -0.1 to -0.7 bar in a glass house study. Plants emerged from the Sharkey clay at a faster rate and over a wider range of soil water potential than from the Dubbs silt loam.

Singh (1983) reported that good emergence of gram and wheat can be achieved upto -5 bar soil water potential whereas satisfactory emergence (65% to 70%) may be obtained upto -10 bar soil water potential in a fine tilled black clay soil. Satisfactory emergence of safflower can be obtained upto -5 bar soil water potential although a soil

water potential of about -2 bar results in a very good germination. The highest value of the emergence rate index of wheat, gram and safflower was obtained at -5, -1.80 and -0.33 bar soil water potential.

sharma (1984) concluded that for obtaining good emergence of barley (82% to 100%), soil moisture stress beyond 5 bars should be avoided in a fine tilled black clay soil. Maximum emergence rate of barley was recorded at -0.33 bar soil water potential and decreased progressively at a slow rate. Decrease in soil water potential beyond -5 bars caused a drastic reduction in emergence rate index.

## 2.2 GROWTH FACTORS

### 2.2.1 Effect of soil water potential on radicle elongation and shoot/root ratio

A number of laboratory experiments have been conducted by various workers to assess the effect of soil water potential on radicle elongation and shoot/root ratio.

Gingrich and Russell (1956) observed that moisture tensions had no significant effect on radicle elongation of corn unless the oxygen concentration was 5.25 per cent or greater. There was progressive reduction in radicle elongation for the higher levels of oxygen concentration with increasing soil moisture tension.

Iden (1961) found that the osmotic pressure of the soil solution generally inhibited root growth of cucumber and beans at 10-30 atmospheric suctions in red and sandy soil. Taylor and Ratliff (1969) observed that the weight and length of shoots of cotton and peanut decreased with decrease in matric potential of soil water. They also concluded that rate of root elongation did not respond to change in the soil matric potential from -0.17 to -7.0 bars for cotton or to changes from -0.19 to -12.5 bars for peanut. Eavis (1972) reported that above -3.5 bars, there was no direct effect of soil water potential on the penetration of pea root in sand.

Newman (1974) observed a marked reduction in flax root growth below -7.0 bar soil water potential. He also noted an increase in shoot/root ratio with decreasing soil water potential which indicates relatively greater depression of root growth than that of shoot growth.

Gupta and Singh (1975) found a non-linear decrease in the root elongation of wheat and mung beans as the soil moisture potential decreased. The root elongation of both the crops was better at osmotic potential than at comparable matric potential. The difference was attributed to water transmission characteristics of the soil. Radicle elongation was reduced to about 50% at 7 bars in case of wheat and at about 8 bars in case of mung.

Bunce (1978) reported that the increase in root resistance of soybean and cotton plants were correlated with lower roots of elongation. The data indicated that shoot/root interaction occurred which affected apparent root resistance to water flow and complicated the interpretation of whole plant data on leaf water potential and transpiration in terms of the flow dependence of root hydraulic characteristics.

Elizzard and Boyer (1980) observed that for soybean, transporting water at a steady rate, water potential difference between soil and root were smaller than between root and leaf over the range of soil water potential from -0.2 to -11 bar.

Heatherly (1980) found that the shoot dry weight and leaf area index of soybean plants grown at -0.6 and -0.7 bar soil moisture potential were significantly less than those of plants grown at -0.3 to -0.5 bar. Root density was significantly less at -0.7 bar. Decrease in soil moisture potential decreased shoot mass. The clay soil gave higher production than the silt loam at all levels of soil moisture potential due to better water availability.

Huck et al. (1981) reported that the soybean plants were grown in uniform sandy soil in a rhizotron with only natural rainfall or supplemental irrigation. Adaptation to dry conditions produced supplemental water had much

larger root systems. Leaf and internodes numbers were comparable but leaf size, internode length, leaf area index, and seed weight were substantially larger when soil water potential was continuously maintained above  $-0.1$  bar by trickle irrigation. Water stress appeared to shift carbohydrate utilization from shoot growth into production of additional root biomass.

Cavaliere and Boyer (1982) observed that elongation occurred in the terminal 1.5 cm of the soybean hypocotyl where the water potential was  $-3.5$  bar. Tissue osmotic potentials generally paralleled tissue water potential so that hypocotyl turgor was maintained. Growth-induced water potentials reflected the local cell enlargement activity and were supported by appropriate osmotic potentials.

### 2.2.2 Effect of soil water potential on transpiration rate and leaf area

Various workers have studied the relationship between the soil water potential and transpiration rate under varying evaporative demand of atmosphere.

Weatherley (1950) studied the internal plant water relation in cotton as affected by soil water suction and evaporative demand of atmosphere. He found that at a certain value of soil water suction, the plant water balance was largely controlled by evaporative demand but if it were below this value it was controlled by both soil water suction

and aerial evaporative conditions. Richards and Weeks (1957) reported that as soil becomes drier and soil suction increases, the suction in the plant root necessary to maintain transpiration increases more rapidly. When the suction approached 15-20 bars, exceedingly high suction or DPD was needed in plant root.

Kramer (1959) stated that the ratio of water absorbing surface to transpiring surface is probably more important than the actual leaf or transpiring surface. Unless water absorption keeps pace with water loss, an internal deficit develops.

Vaadia et al. (1961) reported that the water balance of plants depends on the soil, plant and climatic factors. Absorption of water by plants is initiated and controlled primarily by transpiration. The evaporation of water from the mesophyll cells causes a decrease in turgor pressure thus, lowering the leaf water potential.

Fisher and Hogan (1965) observed that the rate of photosynthesis was moderately sensitive to decrease in plant water stress also retards leaf expansion and reduced leaf area. Slatyer (1967) found that air resistance is about 3 times greater for a leaf 10 cm wide than for only 1 cm wide.

Sionit et al. (1973) observed a rapid increase in transpiration rate immediately after irrigation in both herbaceous and woody plants. As soil water was depleted

the rate of transpiration declined. Blanchet et al. (1977) studied in pot trials, 13 soybean cv from maturity groups 00 to III were grown with soil water supply to give 45, 60, or 100% of maximum transpiration. Leaf area and yield components were measured in 8 cv. with maximum transpiration, transpiration/unit leaf area was almost constant, but use varied, dry conditions decreased both leaf area and transpiration/unit leaf area.

Blanchet and Gelfi (1978) observed that with no water stress, water consumption and total dry matter production were approximately proportional to leaf number up to a leaf area index of 5, beyond this, seed production and water consumption reached maxima but total dry matter still increased with water stress the leaf area, transpiration and seed production were reduced; the photosynthetic activity seed/total dry matter ratio and water use efficiency were higher at low leaf area indices.

Bunce (1978) reported that the relative importance of leaf area expansion and NAR to DM production of soybean and cotton during soil water stress was thus dependent on the degree and duration of stress.

Planchon and Vignes (1978) found in pot and field trial of soybean that highest transpiration rate (at 130 w/m<sup>2</sup> light intensity) was reached in the morning and the rate dropped sharply in the afternoon following a big increase in foliar resistance (from 300 to 700 s/m between 1100 and 1200 h).

Sivakumar and Shaw (1978) observed in field study that rate of leaf area expansion were closely related to changes in soil water potential. RGR of soybeans was negatively correlated with stomatal conductance leaf-water potential and rate of leaf area expansion.

Eavis and Taylor (1979) reported that the total transpiration of soybean ( $\text{cm}^3/\text{day}$ ) from the container increased with leaf area. Transpiration rate ( $\text{cm}^3/\text{cm}^2 \text{ day}$ ) decreased linearly as soil water content decreased, but at any particular soil water content, RL had no significant effect on transpiration rate.

Hipps and Hatfield (1980) reported that the variation in microclimate between watering treatments grew larger as the season progressed and was more pronounced in soybean due to greater leaf areas. The microclimate at a given point in time was heavily influenced by the stress history of the plants.

Meyer and Walker (1981) reported that the pattern of inversion of terminal leaflets and later of lateral leaflet as total available water fell below 40% was observed in soybean cv. oribi grown at Pretoria, South Africa. The interaction between movement, abaxial and adaxial stomatal stress were investigated.

Zeljovich (1981) studied in an experiment using 2 short and 2 long duration soybean cv. detached leaves left

in water in darkness for 5<sub>h</sub> were weighed frequently during drying until they wilted. No significant difference were found in relative turgidity at wilting (72.7-76%), stomatal closure (91.5-95.6%) total or cuticular relative transpiration rates or transpiration control index.

### 2.2.3 Effect of soil water potential on leaf water potential

Various research workers have studied the effect of soil water potential on leaf water potential. Boyer (1970) found that maximum leaf enlargement of soybean, corn and sunflower occurred at leaf water potential of only -1.5 to -2.5 bars and was nearly zero at leaf water potential -4 to -5 bars. The same relationship were found for crop yield also.

Faiz and Hague (1977, 1978) reported that initial drying of the soil had only a slight effect on the leaf relative water content except that a steady value was obtained at 84-85%, but as the soil moisture content was allowed to decline below about 21% the relative water content decreased steeply as a result of high day time evaporative demand. The leaf relative water content recovered partially as low evaporative condition prevailed at night. The day time depletion in leaf relative water content was more severe and the recovery at night was more incomplete with decreasing moisture content in the soil. The day time lowest value of 52-75% relative water content was obtained 1600 h, associated with 12.6% soil moisture content.

Bunce (1978) reported that low relative humidity resulted in low leaf water potential and turgor in all cases and in leaf expansion rate in most cases in soybean and cotton cv.

Carlson et al. (1978) observed in the field experiment that both leaf water potential and leaf conductance related to significantly to imposed soil moisture treatments and to final seed yield and yield components of soybeans.

Wenkert et al. (1978) found that leaf water potential differed very little between sunlight and shaded leaves, so that it appeared that short-term changes in elongation rate resulted from small changes in turgor pressure in field grown soybean.

Hatfield and Carlson (1979) reported that the exact pattern from day to day was highly dependent on atmospheric demand and soil moisture content within the canopy an initial time lag after sunrise was observed before leaf water potential began to decrease; this effect was attributed to radiation interception differences between canopy strata. There were no consistent differences in leaf water potential patterns between two soybean cultivars.

Samet and Cortes (1980) observed a close relationship between leaf water potential and ABA accumulation in soybean under water stress but the relationship was different in the two cv. (a) Chippewa 64 which is fairly drought hardy and

(b) Wilkin which is drought susceptible. Growth of (a) was less affected by the stress (b) did not accumulate as much ABA as (a), yet the leaves from (b) had more negative potentials.

Yadava (1980) observed that the leaf water potential was a better indicator of plant water stress than other physiological parameters, but the stomatal conductance had no relationship with leaf water potential varying from -2 to -19.25 bar in soybean.

#### 2.2.4 Relationship between transpiration rate and leaf water potential

It is well known that the rate at which the water is lost through the stomata is inversely proportional to the resistance of diffusion path and directly proportional to the vapour pressure differences between the inside of the stomatal cavity and some point outside. Internal diffusion resistance depends upon the stomatal aperture which in turn is function of leaf water potential. Transpiration in most plants is controlled by stomatal aperture. Various workers have studied the relationship between transpiration rate and leaf water potential.

Gardner and Denielson (1964) stated that the resistance of water movement in the soil limits the rate of water uptake by roots, the turgor pressure decreases, the stomata start to close, the transpiration rate decreases.

Hiler (1972) observed that the transpiration rate was essentially zero when soil water potential dropped below -5 bars and when leaf water potential fell below -11 bars. At this level the leaf diffusion resistance measured by true markers was very high because of the closure of the stomata of pea.

Bunce (1978) found that at equilibrium an increase in transpiration always resulted in a decrease in leaf water potential. Different response of equilibrium leaf water potential to transpiration rate occurred depending on weather transpiration was altered by changing relative humidity, light intensity or leaf area in soybean and cotton plants.

Rajput and Gupta (1978) reported that the transpiration rate was highest in lentil followed by niger and wheat. The leaf water potential decreased almost linearly with the decrease in soil water potential among the three crops grown under similar soil and environmental conditions.

Boot and Bennett (1980) measured the diurnal process of field grown soybean after varying period of water stress. On plots deprived of water for more than 10 days, canopy, carbon exchange rate, evapotranspiration and stomatal conductance increased up to 1000 h, then declined as leaf water potential declined and turgor reached zero. Good carbon exchange rate/light response curves were obtained on

Bhargava et al. (1976) reported the comparative moisture depletion pattern of soybean and maize grown in a black clay soil of M.P. Lozano et al. (1978) studied in a two year experiment with 4 soybean cv. and 3 levels of soil moisture there was no significant difference in the proportion of unfilled pods due to either of the variables nor was there any interaction between them in relation to seed setting.

Berlato and Bergamaschi (1979) observed that water use was highest between the stage of greatest podding and the stage when 50% of leaves had turned yellow. Daily average water use was highest at 7.4 mm from maximum flowering to maximum podding.

Meyer (1979) used a physiological soybean growth and development model, to stimulate crop performance, seed size, seed yield and crop temperature for dryland and irrigated conditions. It can be used to study detailed physiological process in soybeans, and has been validated for 3 locations.

Momen et al. (1979) reported that moisture stress significantly affected most yield components (weight/seed, seeds/pod, pods/node, number of pods) for both experimental varieties for the 4 stress periods, but important interactions were difficult to identify. Although the both variety differed greatly in some specific yield components, compensation between the different yield components resulted in no consist yield differences between these two experimental varieties.

Wien et al. (1979) observed reduction in main stem length due to moisture stress in cowpea and soybean plants.

Hunter et al. (1980) concluded that soybean responds well to permanent water tables maintained close to the soil surfaces, and high yields of seed are feasible in 80 to 85 days crops.

Jones et al. (1980) discussed the results of a sensitivity analysis with the model, in terms of research needs and in terms of potential problems in stimulating the effects of water stress on crop growth processes.

Karlon et al. (1980) found that the concentration of nutrients (P, K, Ca, Mg, Fe, Mn and Zn) in plants grown with and without irrigation were very similar; however, plant biomass production and therefore nutrient uptake was much greater under the irrigated conditions. Differences in nutrient concentration among the soybean cv. appeared to be related to plant growth stage at the time of sampling. The uptake and distribution of nutrients within the soybean cv. and relationship to yield and further fertilization practices were discussed.

Osman Bin Ysof et al. (1980) studied in an experiment stress plants throughout the growing season. For all treatments leaf and stem dry weight increased throughout the flowering period. Highest grain yields and shoot dry weight were obtained for plants growing on soil

maintained at relatively high soil water levels through out the reproductive growth period. Stress during both flowering and pod filling resulted in significant yield reduction in contrast to well watering was due to an increase in number of pods/plant rather than to seed mass or number of seeds/pod.

\* Sutherland and Danielson (1980) concluded that pod and seed development stages that require the maintenance of an adequate soil water supply; water deficit during flowering depresses yield; and high soil water content through out the pod and seed development stages delays maturation which could decrease yields if the growing season is restricted.

Tambi et al. (1980) supplied adequate moisture in field grown soybean during pod fill thus extended the capacity for N assimilation, via nodule function and nitrate uptake and reduction, to later stages of embryonic development when the plants would otherwise have been water stressed.

Vendeland et al. (1980) observed that the rate of leaf production was very sensitive to water stress at all stages of vegetative development, being reduced to nearly no growth under severe stress. The potential for recovery growth upon release from stress was limited by the time remaining until pods were initiated at the uppermost nodes of the soybean plant.

Wang and Wang (1980) conducted a pot trials with 8 soybean cv. the effects of 4 days without irrigation on stomata was investigated. With holding water increased the diffusive resistance of stomata with cv. Bragg being more sensitive than Sant'Ana, Bossier more sensitive than Florida and JFV-1 more sensitive than Vieoja.

Yaklich and Cregan (1980) studied in each year of (1978-79), 2 sets of 20 pods from each cv. were submerged in water for 0, 1, 6 and 24 h to follow moisture uptake by the pod and seeds. Pods and seeds from groups II-IV contained significantly more moisture than V and VI. Pods of cv. Williams and Celest contained the least amount of moisture in groups III and V, with both having approx. 31.0 and 38.0% m.c. at 6 and 24 h, respectively seed of cv. Ware contained the least moisture (7.5 and 23.8% at 6 and 24 h, respectively) among the 16 cv. in group IV. The result indicate the involvement of the pod exocarp, endocarp and seed coat in providing protection to soybean seed against field weathering.

Snyder et al. (1982) observed that seed yield reductions for all soil water treatments and cultivars ranged from 2% to 27%. Averaged over all stress treatments the later maturing cultivars exhibited a 12% seed yield reduction, whereas the early maturing cultivars had an 18% reduction.

## 2.3 Nitrogen fertilization

### 2.3.1 Content and uptake of nitrogen and its effect on soybean yield

Soybean is not a heavy feeder crop, but when other crops fallow soybean they do not give good yield performance so balanced and timely fertilization is a must for proper development of soybean.

Thorn (1919) suggested that legumes in rotation were the cheapest and more economic means of increasing soil nitrogen. / Lyon and Bizzel (1934) conducted experiment with various legumes alone and in combination with other crops for ten years. They observed that rotations including legumes were superior to all. Soybean was most effective amongst the legumes and large gain of nitrogen in soil was associated with large nitrogen content of crops.

Murneck's experiments (1937) with soybean plants grown under long vs, short days indicated that flowering is accompanied by marked decreases in nitrate content and increases in amino N content of the stems. Murneck also reported that nitrate is fairly uniformly distributed in different regions of the stem during flowering.

Singh et al. (1938) reported that the available nitrogen was relatively high in soils previously cropped to legumes as compared with non-legumes. The amount of nitrogen

was the highest in the environment of the legume roots whether shallow or deep and was low in spring, increasing in summer and once again decreased in rains after which it had risen until October.

Lethwell and Evanse (1951) observed a great demand for nitrogen during the development of pods and beans. There was no indication of cessation of nitrogen absorption by soybeans until maturity. There were indications, however, that the plants were able to utilize nitrogen more effectively in the early stages of growth than in the later stages.

Smith et al. (1955) indicated the beneficial influence of legumes in maintaining soil fertility at a fairly higher levels as compared to rotation without legumes.

Ohlrogge (1964) reported that soybean crop requires 314 kg nitrogen, one half to two third of this requirement may be supplied by nitrogen fixing bacteria and the remaining must come from the soil. Much of this nitrogen is taken up by the plant during pod formation and seed filling.

Shinde and Datta (1964) observed that nitrogen application increased phosphorus uptake markedly.

Hanway and Weber (1971), reported, in field trials in 1963 using 8 cultivars, that total accumulation of nitrogen, phosphorus and potassium followed the same pattern

as that of dry matter accumulation in all the cultivars tested. Rates of accumulation increased as the season advanced. The concentration of nitrogen, phosphorus and potassium in each plant part, except the seeds, usually declined as the season progressed. Of the nitrogen, phosphorus and potassium in the mature seed, about 50% was translocated from other plants part and 50% was taken up from the soil and nodules during seed development.

Harper (1971) observed levels of uptake of nitrogen phosphorus and potassium measured by their disappearance from the solution, were low during the first 30 days after emergence, increased sharply at initial flowering and were highest between full flowering and mid pod filling, uptake was affected markedly by the solution strengths, but phosphorus was the only nutrient removed in direct proportion to its concentration. All the detectable phosphorus was removed from the three lower nutrient levels during pod filling and all the detectable N was removed from weakest solution between initial flowering and the green bean stage. In general the uptake of nitrogen, phosphorus and potassium decreased during the later development stages. The content of nitrogen in the tops decreased from the seedling stage and levelled off, after full flowering phosphorus content increased during the first 30 days, reached the highest levels at initial flowering, decreased until mid pod filling and then levelled off. Potassium content increased slightly from the seedling stage until full flowering and then decreased.

Bangoo and Albrtton (1972) reported a definite relationship between the effect of nitrogen, phosphorus and potassium fertilization on soybean yield and on the nutrient content of both the leaf and grain tissue. Nitrogen, phosphorus and potassium fertilizers all increased the content of these respective elements in the leaves and nitrogen and potassium fertilizer caused an increase of these elements in the grain. Soybean yields showed a positive correlation with nitrogen and potassium. Setty (1974) reported that nitrogen percentage in soybean plant increased with increasing level of nitrogen and decreased with the age of crop.

Agrawal and Narang (1975) studied the effect of graded doses of phosphate viz. 0, 40 and 80 kg P<sub>2</sub>O<sub>5</sub>/ha with 0 and 20 kg N/ha on soybean 'Punjab-1' "Bragg" and "Clark-63" and reported that application of nitrogen and phosphorus increased the seed protein and oil content significantly as compared to content in all the three varieties of soybean.

Courpront and Taisin (1975) observed that for nitrogen, the maximum uptake rate (about 10 kg/ha/day) occurred after the appearance of the first pods, for most of the other elements it occurred in fifteen days preceeding flowering. For potassium and phosphorus the maximum rates of uptake were 8 and 4 kg/ha/day respectively.

Tiwari (1975) concluded in his thesis that no basal nitrogen is needed for soybean if F.Y.M. @ 10 cartload/acre is mixed with the soil at the time of last bakharing.

Pal and Saxena (1976) observed that the nitrogen concentration in stems, leaves and petioles decreased with plant age, whereas in pods the nitrogen accumulation increased. In contrast, nitrogen accumulation in stems, leaves petioles and whole plant followed a sigmoid pattern with plant development while in pods it increased linearly.

Rayer and Hat (1977) found the effect of a wide range of  $\text{NH}_4$  concentration on the uptake and tissue content of phosphorus, potassium, calcium and magnesium in soybean plant at different growth stages. A stimulatory effect of  $\text{NH}_4$  on the uptake and content of phosphorus was observed over the entire concentration range, whereas this effect was observed only upto  $5.00 \mu\text{M}$   $\text{NH}_4$  with respect to potassium at higher levels  $\text{NH}_4$  suppressed the uptake and content of potassium. Inhibition by high levels of  $\text{NH}_4$  was also found for the uptake and content of calcium and magnesium. It was concluded that inhibition in the uptake of potassium, calcium, magnesium by high levels of  $\text{NH}_4$  may be an important factors in the mineral nutrition of soybean plants.

Hatam (1977) reported that the plant nitrogen content increased with nitrogen application but decreased with organic matter application.

Sable and Khuspe (1977) both observed that application of 30-60 kg N/ha to soybean and/or seed inoculation increased the seed yield but decreased seed oil content, where as application of 60-90 kg P<sub>2</sub>O<sub>5</sub>/ha increased the seed oil content as compare to control.

Barni et al. (1978) in field trial in 1975-76 soybean were given 0, 8, 16, 32, 64 or 128 kg N/ha as urea applied 10 cm away from the rows at the begining of flowering. Seed yields ranged from 2.62 t/ha with N<sub>0</sub> N to 2.91 t with 128 kg N but idfferences were not significant yield components plant height and the height of insertion of the 1st pod were also not significantly affected.

Kastori et al. (1979) presented the data on the contents of N, P, K, Ca, Mg, measured at 15 days intervals from 31st May to 31st August and at maturity in the leaves, stems, pods and seeds of soybean cv. Wilkin, steels and Corsoy at Novi Sad in 1976 and 1977. Accumulation of the elements was highest in Corsoy which accumulated most plant dry matter and had the highest seed yield (2.74 t/ha).

Huang (1980) conducted a trial in 1978, 4 soybean cv. were given 0.50 or 100 kg N/ha and LAI and DM, N, P, K, Ca and Mg contents measured at 10 days intervals after emergence. Applied N had a greater effect on seed yield of dwarf early maturing cv. than on fall late maturing cv. DM content was greatest at 50 days and concentration of N, P and K in leaf and stem were highest at 20-40 days after emergence.

✓ Anonymous (1983) reported that maximum soybean grain yield (18.0 g/ha) was recorded from 10 kg N/ha given through FYM which was statistically at par with the yield obtained due to 20 kg N/ha applied through urea in a clay soil. Decreasing N levels caused a marked reduction in soybean yield.

### 2.3.2 Effect of nitrogen application on protein and oil Content of soybean

Fellers (1918) reported that the protein content of soybean increased by the influence of nitrogenous fertilizer.

Wagner (1962) reported that the protein content of soybean increased by the influence of nitrogenous fertilizers.

singh and Singh (1968) reported that the nitrogen application significantly increase the protein content of soybean.

Kesavan and Morachan (1974) observed that the phosphoric acid increased the protein and oil content significantly. Nitrogen had no influence on the seed yield. Nitrogen increased the protein content significantly but had no effect on the oil content. Norman (1974) reported that the influence of nitrogen is prominently seen in increasing the protein content of soybean.

Agrawal and Narang (1975) reported that the application of nitrogen and phosphorus in combination increased seed protein and oil content as compared to control.

### 2.3.3 Correlation studies of the nutrients and other chemical composition of soybean

Albert (1933) observed that calcium had a significant role in symbiotic nitrogen fixation. Nodulation failure occurred below pH 5 regardless of calcium levels. Above that pH calcium had an effect regardless of pH level, indicating its nutritional value.

Horner (1936) observed that nodulation improved in proportion to calcium application. There was a tendency towards a proportional increase in nodulation and growth and similar relationship between calcium and per cent nitrogen in the plant.

O'Kelly and Geiger (1937) observed that when there is a change in the ratio of protein to oil then there is also change in other components of soybean grain; usually there is an inverse relationship between the oil and carbohydrates with protein.

Cartter and Hopper (1942) reported that percentage of sugar increases and decreases with percentage of oil and that when total sugar and oil changes in one direction, the protein content changes in other.

McCally (1937) stated that calcium was required for the growth and normal behaviour of Rhizobium bacteria as well as for effective nodulation in soybean seedling. He

also observed that the order of importance of the elements studied for bacteria was  $Ca > Mg > Ba > K > H$ .

Vitteam & Mulvory (1944), Fuleky (1947) reported that the applied phosphatic fertilizer increased the protein content of the grain.

Ramagnoli (1949) found phosphorus and potash fertilizers to favour oil formation and nitrogen fertilisers result in high protein and seed yield.

Robert et al. (1954) reported highest oil content of beans at the first maturity and decreased progressively with later maturity. However, this decrease was not consistent for all varieties. Protein content of seed, considering all entries varied inversely to the general trend noted for oil content, however, this trend was not consistent among varieties.

Krober and Cartter (1962) studied interrelationship of protein and nonprotein constituents of the soybean such as oil, cellulose, sugars, pentoses, crude fibre, ash and seed size was affected most by changes in protein content. When the protein was increased, they found about 1/3 of the decrease in nonprotein constituents was in sugars, 1/3 in oil and remainder in cellulose and pentoses.

Hartwig and Collins (1962) and Johnson and Barnard (1963) reported a negative correlation between protein and

oil content of soybean grain. Singh and Singh (1968) reported that the protein content of soybean seed increased with the application of phosphorus.

Simirnova - Ikonnikova et al. (1971) observed a negative correlation coefficient (  $r = -0.53$  ) between protein and oil content of seed.

Shannon (1972) reported that yield was more closely correlated with number of pods/plant, 100 seed weight and number of seed/plant than other characters. He also found that the protein content was negatively correlated with oil content.

Smith and Circle (1972) reported a positive correlation between yield and seed size, yield and oil and a negative correlation between yield and protein.

Lal et al. (1973) observed that the eight of the eleven varieties under test showed a negative and significant correlation between protein and oil content of the soybean seed.

Ravankar and Badlie (1975) reported that applied phosphorus increased the protein content of the grain.

Sharma et al. (1977) reported that in field trials in 1970-75 in M.P. at 13 locations, the new soybean cultivars JS-2 out yielded the standard cultivar Clark-63,

Bragg and local Kalitur by 42-55% (average 48.6%), 17.6-60.8% and 23.1-58.1% (average 23.6%), J.S.-2 has 40.1% seed crude protein content 21.3% seed oil content and 1.8% methionine in the crude protein.

Sokolova (1977) showed that composition of amino acid in the seed crude protein of soybean depends on cultivars, soil and climatic conditions. Excessive moisture in the soil during the growth period affects the quantitative contents of amino acids in the crude protein.

Sood et al. (1977) reported that the seed protein content was generally higher in the late maturing varieties and oil content was highest in early sown or early maturing varieties.

Joshi (1980) concluded in his thesis that application of nitrogen alongwith phosphorus increased organic carbon content of soil significantly. He also concluded that the nitrogen application through either source increased the water soluble phosphorus significantly over control. The increasing levels of phosphorus did not cause any significant change in water soluble phosphorus content in soil.

Paliwal (1981) summarised in his thesis that the maximum uptake of nitrogen, phosphorus and potassium in all the cultivars was found at 40 days growth stage and showed decreasing trend at 80 days growth stage. There was significant difference in phosphorus uptake in grain whereas

nitrogen and potassium did not differ significantly in the grain portion of any cultivar. It has been observed that the protein content of the grain increases as the duration of the crop increases whereas the oil content decreases with the increase in duration of the crop.

Tedia (1984) concluded that protein and oil content in soybean grain increased significantly with increasing doses of superphosphate application as compared to control and was maximum with 80 kg dose. Among varieties, "Black soybean" contained the (significantly) higher amount of protein than "JS 72-44" and "JS-2" but "JS-2" contained (significantly) greater amount of oil than "Black soybean".

## MATERIALS AND METHODS

## MATERIALS AND METHODS

The present investigation, entitled "Studies on the growth of soybean in relation to soil moisture and nitrogen stress in a black clay soil" was carried out under Dryland Agriculture Research Project, Indore during kharif season 1984-85. For this study following three experiments were conducted :

1. A pot experiment was conducted in laboratory to study the influence of soil moisture stress on seedling emergence, plumule and radicle growth of soybean.
2. Another experiment was conducted in pot house to study the influence of soil moisture stress on growth and transpiration of soybean.
3. A field experiment was conducted to study the influence of different levels and source of nitrogen on yield, chemical and biochemical composition of soybean.

### PHYSICO-CHEMICAL PROPERTIES OF SOIL

A clayey soil was used for laboratory, pot house and field studies. The various physico-chemical properties of soil used for experimental purpose were determined in the laboratory using standard method which have been given in table-1.

Table 1 - Physico chemical properties of soil

S. NO.	Properties of soil	Value	Method
1.	Mechanical analysis	56.00	International Pipette method (Piper, 1950).
	(a) Clay %	56.00	
	(b) silt %	30.75	
	(c) Sand %	13.25	
2.	pH (1:2)	7.45	Glass electrode pH meter.
3.	EC in mmhos/cm at 25°C (1:2, soil/water ratio)	0.22	Richards (1954)
4.	Calcium carbonate %	4.5	Rapid titration method (Piper, 1950).
5.	Organic carbon %	0.35	Walkley & Black's rapid titration method (Piper, 1950).
6.	Available N (kg/ha)	180.00	Alkaline permanganate method (Subbiah & Asija, 1956)
7.	Available P <sub>2</sub> O <sub>5</sub> (kg/ha)	30.00	Olsen <u>et al.</u> (1954).
8.	Available K <sub>2</sub> O (kg/ha)	500.00	Flame photometer (Chapman & Pratt, 1961).

### 3.1 SEEDLING EMERGENCE STUDIES

#### 3.1.1 Growth medium

Air dried soil samples (0-15 cm depth) were collected, ground and passed through 2 mm sieve and the soil moisture

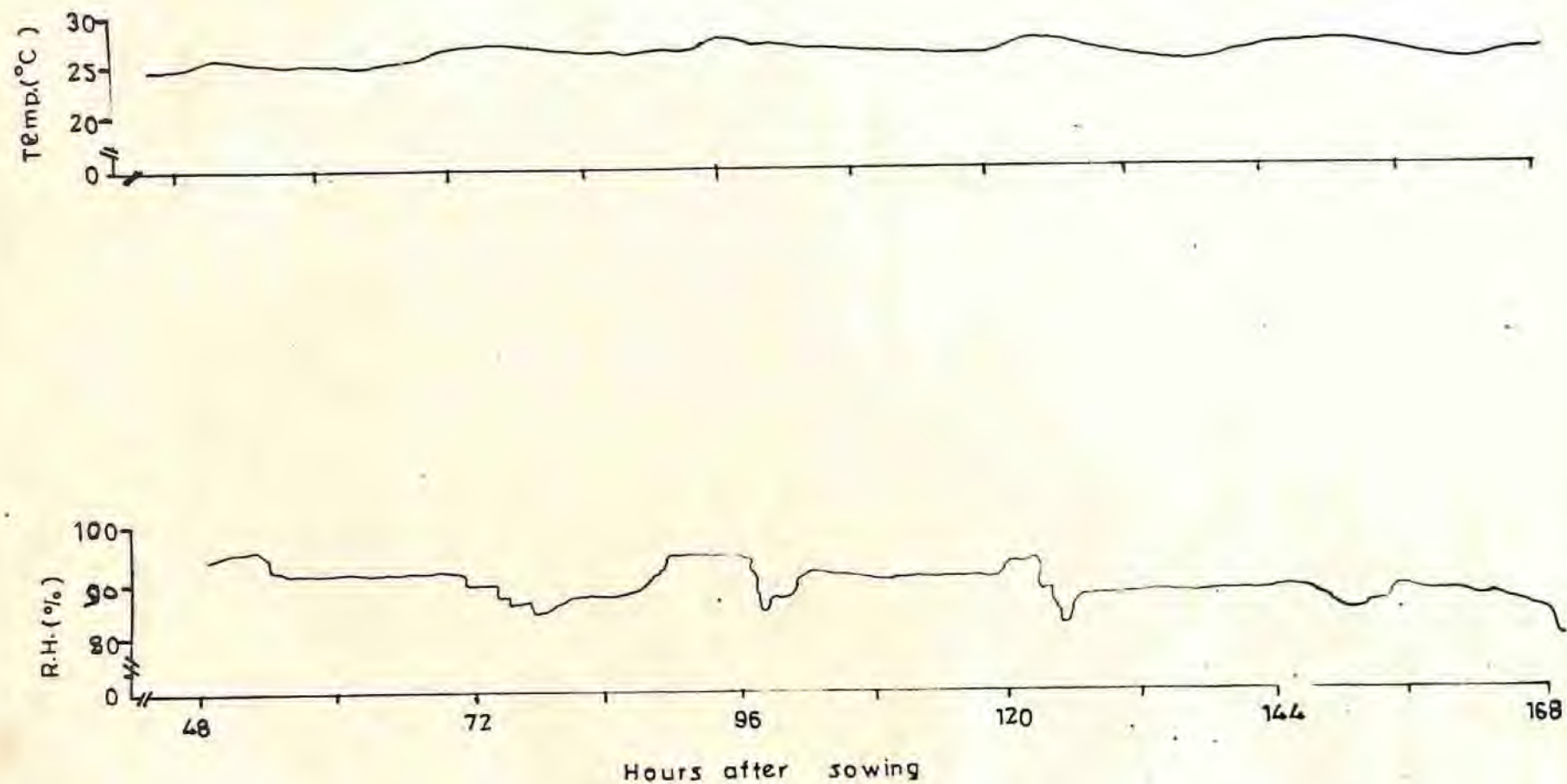


Fig.1. CHANGES IN ROOM TEMPERATURE AND RELATIVE HUMIDITY DURING SOYBEAN EMERGENCE

characteristics were determined by the standard procedure as described by Richards (1949). The soil moisture characteristics curve of the soil used for experimental purpose was determined in the laboratory using pressure plate and pressure membrane apparatus in the 0-1 and 1-15 bars suction range, respectively and the same has been depicted in Fig.2 and appendix-3.

### 3.1.2 Viability test

Viability of the seeds was tested by tetrazolium test. Seeds were soaked in 0.5% tetrazolium solution for 3 to 4 hours and after that they were desected and the colour density developed in the embryo was tested. The development of colour in the embryo is associated with the viability of the seed. Sound and viable seeds develop fast pink colour in the embryo, comparatively fade pink colour is developed in less viable seeds and in the unviable seeds there is no development of pink colour in the embryo. Viability of the seeds was found to be 100 per cent.

### 3.1.3 Creation of desired soil moisture potential

The experiment was conducted in aluminium containers having dimension of 8.5 x 5 cm (diameter x length). Eight levels of soil water potentials were created in these containers to seed their effects on seedling emergence, plumule and radicle elongation of soybean seedlings.

The following levels of soil water potential and corresponding moisture content were created :

<u>Treatments</u>	<u>Moisture per cent by weight</u>	<u>SWP (-bars)</u>
M <sub>1</sub>	34.40	0.33
M <sub>2</sub>	31.44	1.00
M <sub>3</sub>	28.00	3.00
M <sub>4</sub>	24.62	5.00
M <sub>5</sub>	21.80	8.00
M <sub>6</sub>	20.58	10.00
M <sub>7</sub>	18.70	12.00
M <sub>8</sub>	17.46	15.00

These desired soil water potentials were created by adding an appropriate amount of water calculated from moisture desorption data (Fig.2) for a known amount of soil. Before packing the metallic container with soil, total weight of container including soil and water for a desired level of compaction upto a known height was worked out. Metallic containers were packed with dry soil in instalments and simultaneouly required amount of water was added. Finally each container was closed with its lid, and kept for 48 hours to ascertain moisture equilibrium in soil. Ten seeds of soybean were placed at an uniform depth of 2 cm in each container after treating with Thirum 50% by slurry method.

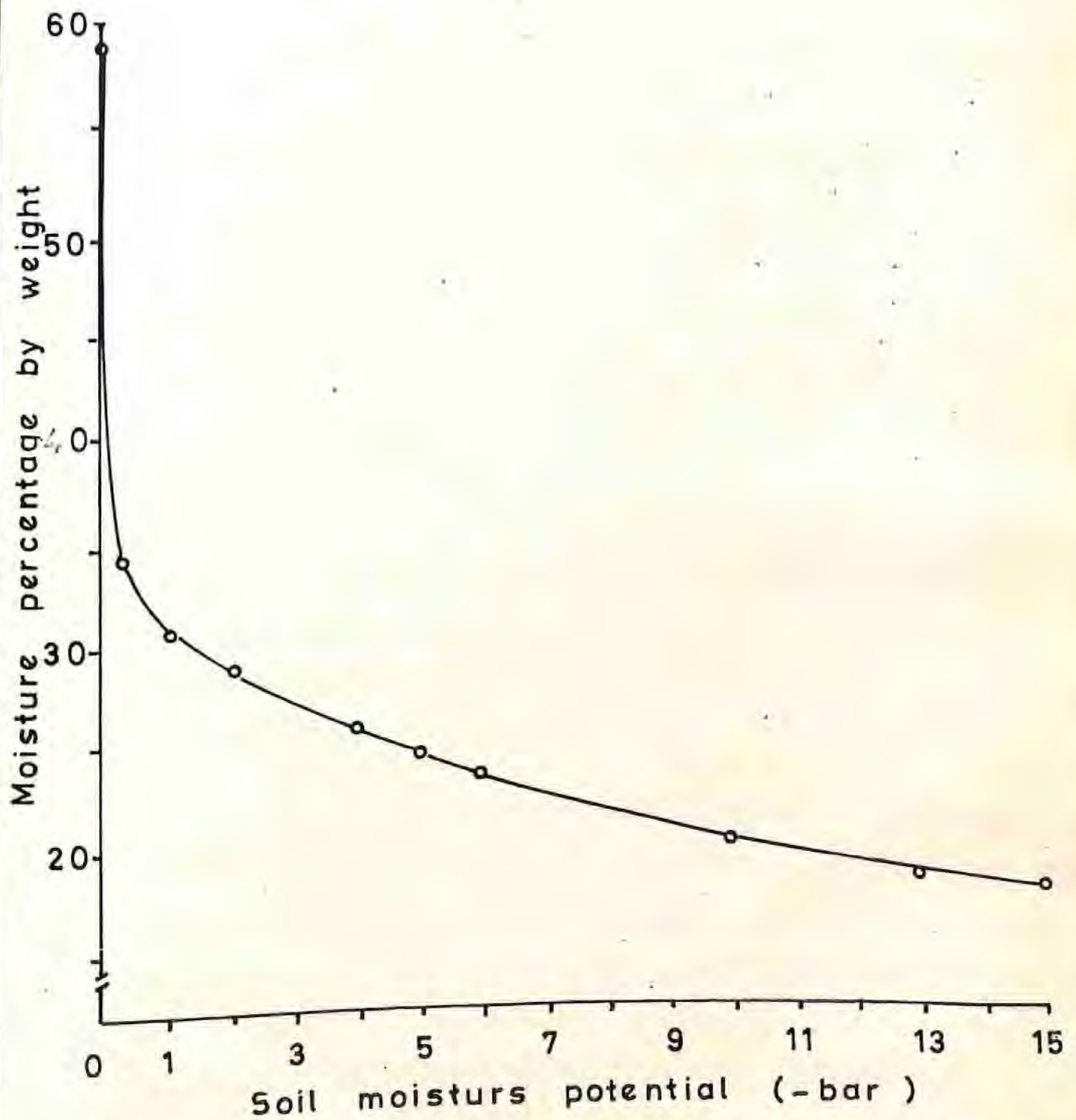


Fig.2. MOISTURE RETENTION CHARACTERISTICS OF DEEP BLACK SOIL DURING DESORPTION



The containers were arranged in a completely randomized design having 12 replications on a table in the laboratory. Centrally located among the containers was a thermohygrograph for recording temperature and humidity. By the side three containers of similar dimensions were also kept for recording potential evaporation during the course of study. Each container was weighed at 12 hours interval and the loss of moisture if any, was made up by adding water to maintain constant soil moisture potential.

### 3.1.4 Observations

Emergence counts were started after 48 hours of sowing and these were recorded regularly at a 12 hours interval upto 168 hours of sowing. Room temperature and relative humidity in the laboratory varied between 24°C to 27°C and 80% to 95% respectively.

At each sampling time one replication was destroyed and the observations on radicle and plumule length from each treatment were made. Before washing the soil in containers sufficient quantity of 3% sodium hexametaphosphate was added to disperse the soil for facilitating the washing. Length of radicle and plumule were measured by putting them straight on graph papers.

Emergence rate index (ERI) was calculated by the formula (Choudhary & Ghildyal, 1970) as given below :

$$ERI = \sum f_i (x - 1)$$

where  $f_i$  is the per cent emergence on  $i$ th day,  $x$  is total number of days in which emergence was completed and  $(x-i)$  is weightage factor for  $i$ th day.

### 3.2 SOIL WATER AND PLANT RELATION STUDIES FOR SOYBEAN

An experiment was conducted in a pot house during the period from 15th July, 1985 to 26th August, 1985 to study the effect of different levels of soil water potential on different growth parameters, transpiration rate, root and shoot growth of soybean cultivar JS 72-44 grown in a clayey soil. The atmospheric temperature and humidity during the experimental period varied from 19°C to 32°C and 78.5% to 96% respectively. The potential evaporation recorded in the pot house varied from 1 mm to 10 mm/day.

#### 3.2.1 Growth medium

A clay soil collected from field No.24 of experimental area of Dryland Agriculture Research Project, College of Agriculture, Indore (M.P.) was passed through a 2 mm sieve. Numbered plastic pots of 22 cm height and 25 cm in diameter were weighed. The volume of the plastic buckets was calculated and then the quantity of oven dry soil to be packed in each bucket was worked out. The quantity of soil calculated for each pot was packed at a bulk density of 1.20 g/cm<sup>3</sup>. At the time of packing the fertilizer urea and superphosphate were added to give 20 ppm N and 40 ppm

P205. The quantity of water to be added to each treatment for different moisture levels was calculated. After two wetting and drying cycles the calculated amount of water was added to each pot to achieve desired moisture level according to treatments. Four healthy seeds of soybean in each pot at 2 cm depth were sown on 8th July, 1985. The surface of each pot was covered with glass wool and perforated polyethylene sheets to check evaporation loss. After one week, only two healthy plants were retained in each pot.

### 3.2.2 Details of treatments

The total number of pots were 30 in which following treatments were allotted :

1. (M<sub>1</sub>) 34.40% soil moisture content on weight basis (-0.33 bar SWP).
2. (M<sub>2</sub>) 30.00% soil moisture content on weight basis (-1.2 bar SWP).
3. (M<sub>3</sub>) 26.78% soil moisture content on weight basis (-4 bar SWP).
4. (M<sub>4</sub>) 20.58% soil moisture content on weight basis (-10 bar SWP).
5. (M<sub>5</sub>) 17.46% soil moisture content on weight basis (-15 bar SWP).

Each treatment was replicated 6 times and one replication was destroyed for root sampling and dry matter production at each sampling date i.e. 7, 14, 21, 28, 35 and 42 days after sowing.

### 3.2.3 Observations :

The following observations were recorded :

- i) Growth attributing characters viz. plant height, number of leaves, leaf area, fresh and dry weight of plant under different treatments.
- ii) Growth of soybean roots at different times.
- iii) Loss of soil water through transpiration.

### 3.2.4 Growth factors

#### (i) Leaf area :

The total leaf area per plant was determined at different times intervals using following relation given by Krishnamurthy et al. (1974):

$$\text{Leaf area} = L \times W \times K$$

where L = length of leaf, W = width of leaf and K = constant factor. The factor K was estimated using leaves at different stages of growth and was found to be 0.75.

(ii) Shoot weight :

Shoot portion was cut near the soil surface and its fresh and oven dry weights (dried at 65°C for 48 hours) were recorded.

(iii) Root weight :

Sampling of roots from destroyed pots was done and the roots from each pot were recovered by washing out the soil with a gentle stream of water and its fresh and oven dry weight were recorded.

(iv) Stem height :

The stem height was measured at different time interval using a standard scale. The height was measured from soil surface to the apical portion of stem.

(v) Transpiration rate :

The amount of water used by transpiring plant was determined by weighing the pot every week with the help of a balance. Transpiration rate was calculated by dividing the amount of water used by plant per day with the leaf area of that plant. The transpiration rate was expressed as loss of water in grams per unit leaf area per day ( $\text{g}/\text{cm}^2/\text{day}$ ). Three similarly packed pots without plants were used to determine evaporation, which was observed to be negligible.

### 3.2.5 Computation of some growth parameters

(a) Shoot/root ratio :

It was calculated by dividing oven dry weight of shoot with that of root for the same sampling date.

(b) Relative stem height :

It was computed as the ratio of stem height of plant under stress condition to the stem height of plant under control (No stress) condition.

(c) Relative leaf area :

It was computed as the ratio of leaf area of plant under stress condition to the leaf area of plant under control condition.

(d) Relative dry weight of roots and shoots :

It was computed as the dry weight of root and shoot under stress condition to the respective weights under control conditions.

(e) Relative transpiration rate :

It was computed as the ratio of transpiration rate of the plant under stress condition to that of plant under control (No stress) conditions.

### 3.3 FIELD EXPERIMENT

A field experiment under rainfed conditions was laid out in randomized block design with nine treatments, at the College of Agriculture Farm, Indore in field number 24 (the physico chemical properties of the experimental soil are given in table-1) during the kharif season of 1984-85. Each treatment was randomized and replicated three times. The gross plot size was 14 m x 7.2 m and after leaving nonexperimental margin on either side the net experimental plot size was 12 m x 6.3 m. Soybean crop (JS 72-44) was sown on 30th June, 1984 and harvested on 11th October, 1984. Soybean seed at the rate of 100 kg per hectare were sown at row to row distance of 45 cm and plant to plant distance of 3 cm at 2 to 3 cm deep in soil. The plan of layout is shown in Fig.3.

#### 3.3.1 Details of treatments

In all there were nine treatments. The details of the different treatment combinations were as under :

- (T<sub>1</sub>) Control - No fertilizer but only culture treatment.
- (T<sub>2</sub>) N<sub>20</sub> - Recommended dose of 20 kg N/ha through urea.
- (T<sub>3</sub>) N<sub>10</sub> - Nitrogen at the rate of 10 kg N/ha through urea.

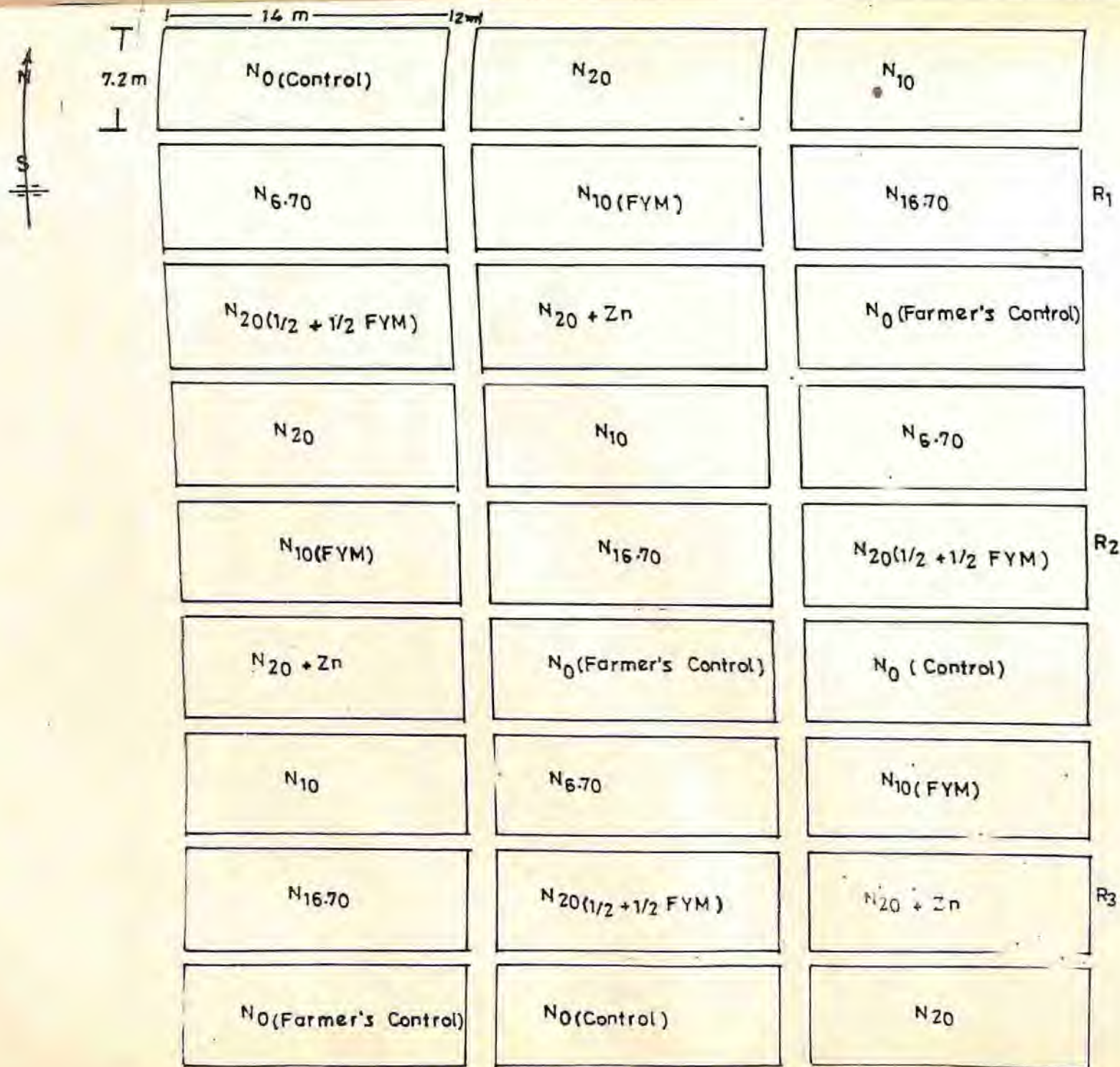


Fig. 3. PLAN OF LAYOUT OF FIELD EXPERIMENT

- (T<sub>4</sub>) N<sub>6.7</sub> - Nitrogen at the rate of 6.7 kg N/ha through urea.
- (T<sub>5</sub>) N<sub>10</sub> FYM - Nitrogen at the rate of 10 kg N/ha through farm yard manure.
- (T<sub>6</sub>) N<sub>16.7</sub> - Nitrogen at the rate of 16.7 kg N/ha through urea.
- (T<sub>7</sub>) N<sub>20</sub>( $\frac{1}{2}$ + $\frac{1}{2}$  FYM) - Nitrogen at the rate of 20 kg N/ha,  $\frac{1}{2}$  through urea and rest half through farm yard manure.
- (T<sub>8</sub>) N<sub>20</sub>+Zn - Nitrogen at the rate of 20 kg N/ha through urea alongwith 25 kg/ha ZnSO<sub>4</sub>.
- (T<sub>9</sub>) Farmer's method - No fungicide, no culture and no fertilizer.

### 3.3.2 Application of fertilizer and sowing

The requisite quantity of nitrogen was applied for different treatments as basal dose at the time of sowing and 40 kg P<sub>2</sub>O<sub>5</sub> per hectare was applied uniformly at the time of sowing. Zinc was also applied in treatment T<sub>8</sub> as basal dose using ZnSO<sub>4</sub> @ 25 kg/ha. No potassium was added as the soil was already rich in potassium content. Basal placement of fertilizer were done about 4 cm deep in the soil and about 2 cm beneath the seed.

### 3.3.3 Observations

The following observations were recorded :

- (1) Grain and straw yield and its attributing characters under different treatments.
- (ii) Soil chemical analysis for two layers (0-15 cm, 15-30 cm layer) before sowing and after harvest of crop for available N, P, K, Ca and Mg.
- (iii) Uptake of N, P, K, Ca and Mg by soybean crop as influenced by different treatments.
- (iv) Protein and oil content of soybean as affected by different treatments.

### 3.3.4 Analytical techniques

#### (a) Collection and preparation of the materials

##### (1) Soil samples :

The surface soil samples from 0-15 cm and 15-30 cm were collected randomly with the help of soil sampling tube before sowing and after crop harvest from each plot. The samples were mixed thoroughly and dried in air, crushed, sieved through 2 mm sieve and used for analysis.

##### (2) Plant samples :

The plant samples from each plot were collected randomly from the area of net plot at maturity stage of the crop. Whole mature plant samples were dried in an oven at 60°C temperature for about 24 hours. The grain was kept separately from the straw. Samples of grain and straw were

prepared by finally grinding with the help of mechanical grinder.

These samples were analysed for nitrogen (protein) phosphorus, potassium, calcium, magnesium and oil content by standard methods as described in following paragraphs.

(b) Soil analysis

The soil samples were analysed for various factors as discussed below briefly :

(1) Available Nitrogen :

The soil samples were analysed for available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956). Twenty grams soil samples were taken in one litre flask and to it were added 100 ml of 0.32%  $KMnO_4$  and 2.5% NaOH each. The flask was immediately connected to distillation assembly and heated. The distilled ammonia was collected in N/10  $H_2SO_4$  using methyl red indicator. The excess sulphuric acid was titrated against N/10 NaOH. Results have been expressed in kilogram of nitrogen per hectare.

(2) Available phosphorus :

The soil samples were analysed for available phosphorus by using Klett colorimeter method (Olsen et al. 1954).

(i) Preparation of standard curve :

Dissolved 0.1916 g of pure dry  $KH_2PO_4$  in one litre

of distilled water. This solution contained 100 micro gram  $P_2O_5$  per litre. Prepared this as a stock standard solution of phosphate. 10 ml of this solution was diluted to 1,000 ml with distilled water. This solution contained 1 microgram (0.001 mg) of  $P_2O_5$  per millilitre. Then 1, 2, 4, 6 and 10 ml of this solution were taken in separate 25 ml measuring flasks, 5 ml of the extractant solution and 5 ml of molybdate reagent and diluted with distilled water to about 20 ml. After the addition of 1 ml of  $SnCl_2$  solution it was diluted to 25 ml mark and then contents were shaken vigorously. After 10 minutes the blue colour of the solution was measured on the photoelectric colorimeter by using red filter (660 nm). The meter reading was plotted against microgram of  $P_2O_5$  and standard curve was prepared accordingly.

(ii) Extraction :

One gram of soil sample was taken with 20 ml of 0.5 M  $NaHCO_3$  of pH 8.5 as an extractant (Olsen et al. 1954) together with 0.5 g of Darco G-60 (Free from phosphorus). The contents were shaken for 30 minutes in 100 ml conical flask and then filtered through Whatman filter paper number 40.

(iii) Development of colour :

5 ml of the colourless filtrate was taken in 25 ml of volumetric flask for determination and then 5 ml of ammonium molybdate hydrochloric acid solution was added. The contents were diluted to about 22 ml. Now one ml of working solution

of stannous chloride was added to each flask to develop blue colour. The contents of flask were shaken well and diluted to mark. Colour intensity was measured in Klett summerson photoelectric colorimeter within 10 minutes using red filter after setting the instrument to zero with blank prepared. The amount of  $P_2O_5$  was calculated in kg/ha.

(3) Available potassium :

One gram of soil was shaken with 100 ml of neutral normal ammonium acetate solution as an extractant in 200 ml conical flask for 30 minutes and then filtered through Whatman No.40 filter paper. The amount of potassium present in extract was determined by Flame photometer as described by Black (1965). The results were calculated as  $K_2O$  in kg/ha.

Extract is also used for determination of exchangeable calcium and magnesium.

(4) Exchangeable calcium :

Exchangeable calcium content was estimated by Versenate method. In this method 10 ml of aliquot taken in conical flask and added 10 ml of 15% NaOH, then 2 to 4 drops of calcone indicator, the colour was raddish and titrated with N/100 EDTA solution. At the end point of titration, colour changed raddish to violet colour and burette reading was recorded. The amount of exchangeable calcium was calculated in kg/ha.

(5) Exchangeable magnesium :

Exchangeable magnesium content was not estimated separately. For this estimation, calcium plus magnesium was estimated by Versenate method. After that estimation calcium reading was minused from calcium plus magnesium reading. For the estimation of calcium and magnesium 10 ml of aliquot was taken in conical flask and added 10 ml of buffer solution ( $\text{NH}_4\text{Cl} + \text{NH}_4\text{OH}$ ) and then added EBT indicator 2 to 4 drops and titrated with N/100 EDTA solution. At the end point colour was blue green. Then the burette reading was recorded. The amount of exchangeable magnesium was calculated in kg/ha.

(c) Plant analysis :

The methods adopted for different factors involved in plant analysis are discussed briefly as under :

(1) Determination of nitrogen :

Nitrogen was determined by micro Kjeldhal method, for which 100 mg of plant sample was digested in 100 ml Kjeldhal flask with concentrated  $\text{H}_2\text{SO}_4$  in presence of triple salt mixture consisting of potassium sulphate, copper sulphate and selenium powder in the ratio of 100:20:0.5. The digested material was transferred to distillation unit and was distilled with 10 ml of 45% sodium hydroxide solution. The distilled ammonia was collected in 2% boric acid solution. After complete distillation the distillate was titrated

against N/50 sulphuric acid. The equivalent amount of nitrogen was calculated and result was expressed as content of nitrogen in percentage. The process is described in detailed by Piper (1950).

(2) Determination of phosphorus :

(1) Extraction :

One gram of oven dried plant sample was digested in diacid mixture consisting of concentrated nitric acid and 72% perchloric acid in the ratio of (2:1). The digested material was filtered through Whatman filter paper No.40 and diluted to 100 ml mark. Filtrate was used for determination of phosphorus, potassium, calcium and magnesium.

(1.1) Development of colour :

10 ml of aliquot from the colourless filtrate was taken in 100 ml volumetric flask for determination and then 5 ml each of 0.25% ammonium metavanadate and 5% ammonium molybdate were added to it to develop yellow colour. The volume was made, solution was shaken well and kept for 30 minutes and colour intensity was measured on a Klett summerson colorimeter using blue filter (660 m). The intensity was matched with intensities of different standard phosphorus solution as described by Jackson (1958). The results were expressed as content of phosphorus in percentage.

(3) Determination of potassium :

5 ml of the aliquot of the filtrate was taken in 100 ml volumetric flask and was diluted to mark with distilled water. The potassium content in extract was estimated by Flame photometer as described by Black (1965). The results were expressed as content of potassium in percentage.

(4) Determination of calcium :

10 ml of the aliquot of the filtrate was taken in conical flask and added 10 ml of 15% NaOH then 2 to 4 drops of calcone indicator, the colour was raddish and titrated with N/100 EDTA solution. At the end point colour was violet and burette reading was recorded. The results were expressed as content of calcium in percentage.

(5) Determination of magnesium :

For this estimation, calcium plus magnesium was estimated. After that calcium reading was minused from calcium plus magnesium. For the estimation of calcium plus magnesium 10 ml of aliquot of the filtrate was taken in conical flask and added 10 ml of buffer solution ( $\text{NH}_4\text{Cl} + \text{NH}_4\text{OH}$ ) and then added EBT indicator 2 to 4 drops and titrated with N/100 EDTA solution. At the end point colour was blue green and burette reading was recorded. The results were expressed as content of magnesium in percentage.

(d) Grain analysis

(1) Determination nitrogen, phosphorus, potassium, calcium and magnesium :

These five nutrients in grain sample was determined by the same process as described earlier for the nitrogen, phosphorus, potassium, calcium and magnesium in plant samples. The content of these nutrients was expressed in percentage.

(2) Determination of protein :

Protein was estimated by analysing the grain sample for total nitrogen content by micro-kjeldhal procedure as described by Piper (1950) and per cent nitrogen was multiplied by 6.25% to get the per cent protein.

(3) Determination of oil :

Oil content was estimated by extracting oil with petroleum ether by soxhlet extraction method as described by Knowles and Watkin (1950). In this method 2 grams of oven dried grinded material taken and transferred it in a previously prepared thimble. Plugged the mouth of thimble with fat free absorbant cotton. The clean, dry receiver flask from the soxhlet assembly was taken and weighed it accurately. Introduced the thimble with sample into the soxhlet. Assembled the apperatus and filled soxhlet with petroleum ether by pouring it through the condenser at

the top by means of a glass funnel. The amount of solvent was taken about  $1\frac{1}{2}$  times the capacity of the soxhlet. Placed the apparatus on a water bath at  $60^{\circ}\text{C}$ , fixed by clamps to a retort stand and started cold water circulation in the condenser. Extracted about 8 hours roughly (about 250 times). After the extraction was over, removed the thimble with material from soxhlet. Assembled the apparatus again and heated it on the water bath to recover all the ether from the receiver flask. The flask now contained only the crude fat. Disconnected the receiver flask, wiped the out side of the flask thoroughly with a clean dry cloth to remove the film of moisture and dust and dried it in a hot air oven at  $100^{\circ}\text{C}$  for one hour, cooled in a desiccator and weighed. The results were expressed as content of oil in percentage.

### 3.3.5 Methods of statistical analysis

The data were analysed by method of analysis of variance as described by Fisher (1950). The structure of analysis of variance is given below. The design of experiment was simple randomized block design with three replications.

Skeleton of analysis of variance

S.V.	D.F.	S.S.	M.S.S.	Fcal Table value at	
				5%	1%
Blocks	2				
Treatments	8				
Error	16				
Total	26				

The null hypothesis was tested by the F test which revealed the significance of treatment effect critical difference between two treatment means. The critical difference for treatment means was calculated by using equation given by Panse and Sukhatme (1957). The standard error of means and coefficient of variation were calculated from error mean square as follows :

$$S.E.m. = \pm \sqrt{\frac{EMS}{r}}$$

$$CV (\%) = \sqrt{\frac{EMS}{G.M.}} \times 100$$

$$C.D. 5\% = S.E.m. \times \sqrt{2} \times \text{table 't' value at } 5\%$$

$$C.D. 1\% = S.E.m. \times \sqrt{2} \times \text{table 't' value at } 1\%$$

## RESULTS

## RESULTS

Pot house studies were conducted to study the influence of different levels of soil water potential on seedling emergence plumule and radicle growth, transpiration rate and growth of soybean (JS 72-44) during vegetative growth period. A field experiment was also conducted to study the effect of different levels of nitrogen applied through urea and farm yard manure on yield, chemical and biochemical composition of soybean plants. Present chapter deals with the results obtained in pot house and field experiments.

### 4.1 SEEDLING EMERGENCE STUDIES

#### 4.1.1 Seedling emergence :

The data obtained on seedling emergence as influenced by different levels of soil water potential (S.W.P.) have been depicted in Fig. 4 and table-2. It is evident from the data that higher seedling emergence of soybean at any time was obtained at field capacity (-0.33 bars SWP) moisture content and decreased with progressive decrease in SWP. The final emergence of soybean in SWP range of -0.33 to -5 bars ranged in between 98.10 to 65.00% respectively. Further decrease in SWP beyond -5 to -15 bars caused a drastic reduction in seedling emergence. The seedling emergence recorded after 168 hours of sowing at SWP of -8, -10, -12 and -15 bars was 44.26, 36.80, 24.80 and 21.85% respectively.

Table 2 - Soybean seedling emergence (%) as influenced by different levels of soil water potential.

SWP (-bars)	Time after sowing (hours)												Final emergence rate index
	48	60	72	84	96	108	120	132	144	156	168		
0.33	-	10.60	16.60	20.50	32.62	48.22	68.15	86.40	95.00	97.70	98.10	395.56	
1	-	-	14.20	16.10	22.00	30.20	50.42	61.50	68.40	78.00	86.25	292.04	
3	-	-	10.62	12.50	15.60	20.85	38.60	51.95	62.15	70.10	78.96	221.63	
5	-	-	-	-	10.50	15.26	27.50	40.20	54.20	60.75	65.00	140.70	
8	-	-	-	-	-	10.25	20.10	34.60	40.55	42.10	44.26	80.75	
10	-	-	-	-	-	3.30	15.50	25.20	31.00	36.50	36.80	62.00	
12	-	-	-	-	-	-	-	16.80	18.70	24.20	24.80	18.70	
15	-	-	-	-	-	-	-	3.40	10.15	18.50	21.85	10.15	

(Each figure is an average of three replications)

S. E.m.  $\pm$  = 0.52

C. D. 5% = 1.58

C. D. 1% = 2.19

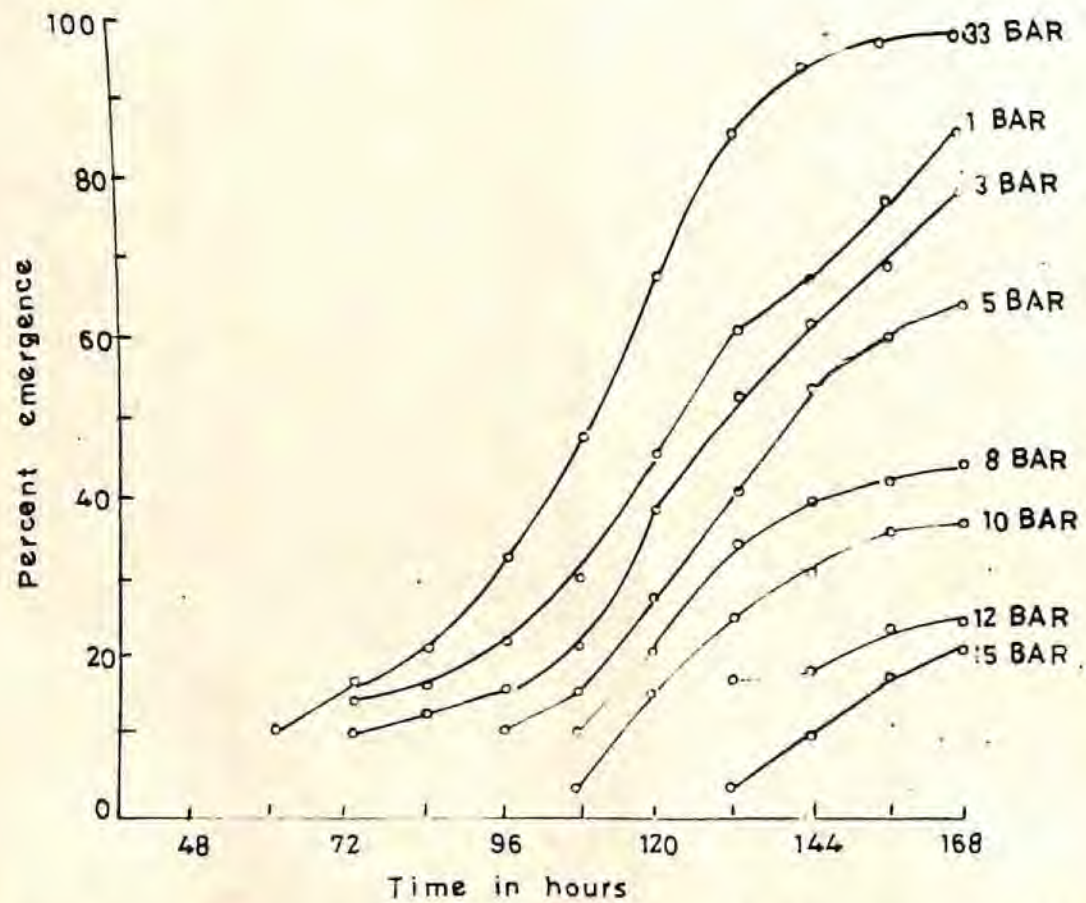


Fig-4. SEEDLING EMERGENCE OF SOYBEAN AS INFLUENCED BY DIFFERENTI LEVELS OF SOIL WATER POTENTIAL

It is evident from the data (Fig. 4 and table-2) that decreasing soil water potential in the range of -0.33 to -15 bars caused a progressive delay in seedling emergence of soybean. Emergence started after 60 hours of sowing when SWP was maintained at -0.33 bars. Decrease in SWP upto -1, -3, -5, -8, -10, -12 and -15 bars caused delay in seedling emergence by 12, 12, 36, 48, 48, 72 and 72 hours respectively. It is also obvious from the data depicted in Fig. 2 that rate of seedling emergence was higher at field capacity moisture content (-0.33 bars) which progressively decreased with decreasing SWP upto -15 bars. The maximum emergence rate index (ERI) was recorded at -0.33 bars SWP and decreased gradually with decreasing SWP upto -5 bars and further decrease in SWP upto -15 bars caused a drastic reduction in ERI leading to a minimum value of 10.15 at -15 bars SWP. The final emergence after 168 of sowing (Y) was significantly correlated with SWP (X) ( $r = -0.98^{**}$ ) in the range of -0.33 to -15 bars which is represented by the regression equation  $Y = 93.4 - 5.3X$ .

#### 4.1.2 Plumule and radicle growth

The data on plumule and radicle growth of soybean as affected by different treatments have been presented in table 3 and 4 respectively. It is evident from the data that in general the different levels of SWP under consideration caused significant differences in plumule

Table 3 - Plumule length of soybean (mm) as influenced by different levels of soil water potential.

SWP (-bars)	Time after sowing ( hours )											
	48	60	72	84	96	108	120	132	144	156	168	
0.33	-	18.8	45.0	56.3	78.8	89.1	99.4	117.0	138.6	151.0	160.8	
1	-	-	15.6	45.1	71.1	79.3	85.8	98.0	106.0	117.3	128.4	
3	-	-	12.0	35.6	59.9	63.2	66.4	69.8	76.3	83.4	90.0	
5	-	-	-	-	29.1	41.1	57.3	60.4	65.5	71.0	76.3	
8	-	-	-	-	-	28.8	40.0	48.6	53.6	61.2	67.4	
10	-	-	-	-	-	28.6	31.3	40.0	43.3	46.7	50.0	
12	-	-	-	-	-	-	-	27.1	30.8	35.3	41.1	
15	-	-	-	-	-	-	-	26.2	29.1	32.2	35.5	

(Each figure is an average of 3 replications)

S.E.m.  $\pm$  = 0.28

C.D. 5% = 0.84

C.D. 1% = 1.16

Table 4- Radicle length of soybean(mm) as influenced by different levels of soil water potential.

SWP (-bars)	Time after sowing (hours)											
	48	60	72	84	96	108	120	132	144	156	168	
0.33	-	16.4	30.2	50.3	70.2	83.4	94.8	110.0	130.5	138.2	150.0	
1	-	-	10.2	38.1	65.4	74.0	81.6	89.3	95.7	104.0	115.3	
3	-	-	8.8	29.8	50.0	53.1	57.6	60.8	65.6	70.3	78.6	
5	-	-	-	-	25.6	38.3	46.4	52.0	58.1	61.5	65.8	
8	-	-	-	-	-	25.3	36.1	41.4	46.6	51.7	56.1	
10	-	-	-	-	-	24.9	28.6	32.0	38.4	40.8	44.6	
12	-	-	-	-	-	-	-	24.6	29.9	32.6	35.5	
15	-	-	-	-	-	-	-	24.2	28.5	30.3	30.4	

(Each figure is an average of 3 replications)

S.E.m.  $\pm$  = 0.433

C.D. 5% = 1.30

C.D. 1% = 1.80

and radicle growth of soybean. Maximum plumule and radicle growth was observed at -0.33 bars SWP and decreased significantly with decreasing SWP upto -15 bars. The maximum plumule length of 160.8 mm was recorded after 168 hours of sowing at -0.33 bars SWP which decreased to 128.4, 90.0, 76.3, 67.4, 50.0, 41.1 and 35.5 mm respectively at -1, -3, -5, -8, -10, -12 and -15 bars SWP. Similarly maximum radicle length recorded after 168 hours of sowing was 150.0 mm at -0.33 bars and decreased to 115.3, 78.6, 65.8, 56.1, 44.6, 35.5 and 30.4 mm respectively at -1, -3, -5, -8, -10, -12 and -15 bars SWP. The final plumule and radicle length (Y) recorded after 168 hours of sowing were significantly correlated with SWP (X) in the range of -0.33 to -15 bars which may be represented by the regression equations as given below :

(i)  $Y = 132.79 - 7.59X$  ( $r = -0.92^{++}$ ) for plumule length in mm

(ii)  $Y = 120.03 - 7.06X$  ( $r = -0.91^{++}$ ) for radicle length in mm

#### 4.1.3 Relative emergence, plumule and radicle growth

The data on the relative seedling emergence, plumule and radicle growth of soybean as a function of SWP have been presented in table 5 and depicted in Fig. 5. It is obvious from the data that emergence, plumule and radicle growth decreased with decreasing SWP in general. The decrease in per cent emergence of soybean was almost linear in -0.33 to

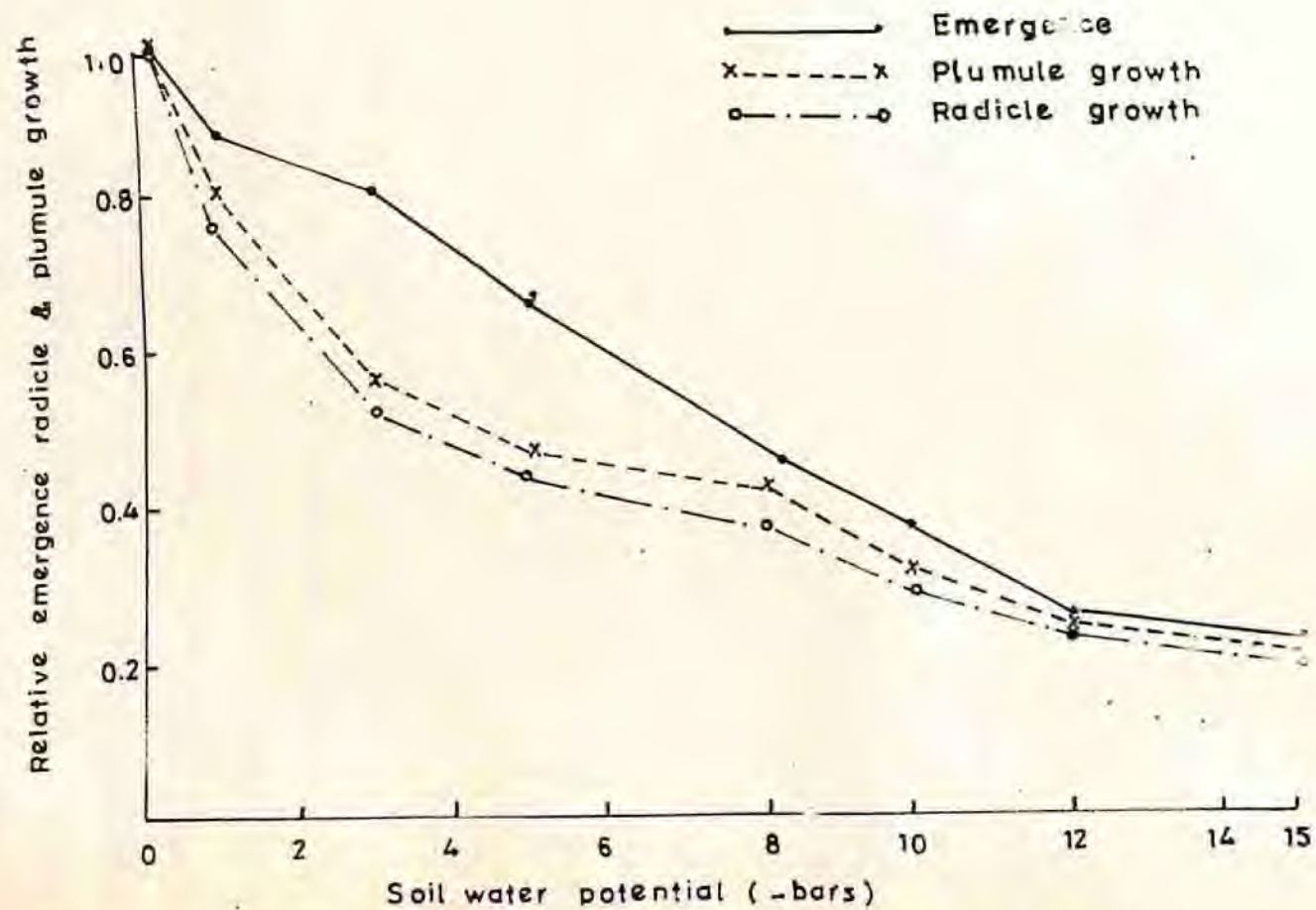


Fig. 5. INFLUENCE OF SOIL WATER POTENTIAL ON RELATIVE EMERGENCE, PLUMULE AND RADICLE GROWTH OF SOYBEAN

Table 5 - Relative seedling emergence, radicle and plumule growth of soybean after 168 hours of sowing under different levels of soil water potential.

Soil water potential (-bars)	Relative emergence	Relative plumule growth	Relative radicle growth
0.33	1.00	1.00	1.00
1	0.88	0.80	0.77
3	0.80	0.56	0.52
5	0.66	0.47	0.44
8	0.45	0.42	0.37
10	0.37	0.31	0.30
12	0.25	0.25	0.24
15	0.22	0.22	0.20
S.Em. $\pm$	0.006	0.002	0.003
C.D. 5%	0.018	0.006	0.009
C.D. 1%	0.025	0.008	0.012

-12 bars SWP and further decrease in SWP from -12 to -15 bars did not affect the emergence. The relative emergence decreased from 1.0 to 0.6 with the decrease in SWP from -0.33 to -6 bars. The trend in the decrease of relative plumule and radicle length was almost similar through out the SWP range of -0.33 to -15 bars. As is noticed (Fig. 5) that there was a sharp decline in relative plumule and radicle growth of soybean from 1 to about 0.5

as the SWP decreased from -0.33 to -3 bars. Further decrease in SWP from -3 to -12 bars caused decrease in plumule and radicle growth as relatively slow rate. In SWP range of -12 to -15 bars there was almost no change in relative plumule and radicle growth.

#### 4.2 GROWTH AND TRANSPIRATION OF SOYBEAN IN RELATION TO SOIL WATER POTENTIAL

Periodical observations on various growth parameters of soybean viz. plant height, number of leaves, green leaf area, weight of shoots, weight of roots, shoot/root ratio and transpiration rate of soybean as affected by different levels of soil water potential were made and have been given in appendices 4 to 19.

##### 4.2.1 Stem height and leaf area

Average plant height and leaf area recorded at weekly interval as influenced by different treatments have been given in appendix 4 and 6 and relative stem height and leaf area have been depicted in Fig. 6. It is evident from the data (Fig. 6 a) that relative plant height (plant height under stress conditions divided by plant height recorded at field capacity moisture content) decreased almost linearly from 1 to 0.35 as SWP decreased from -0.33 to -10 bars. Further decline in SWP from -10 to -15 bars caused only a marginal decrease from 0.35 to 0.25.

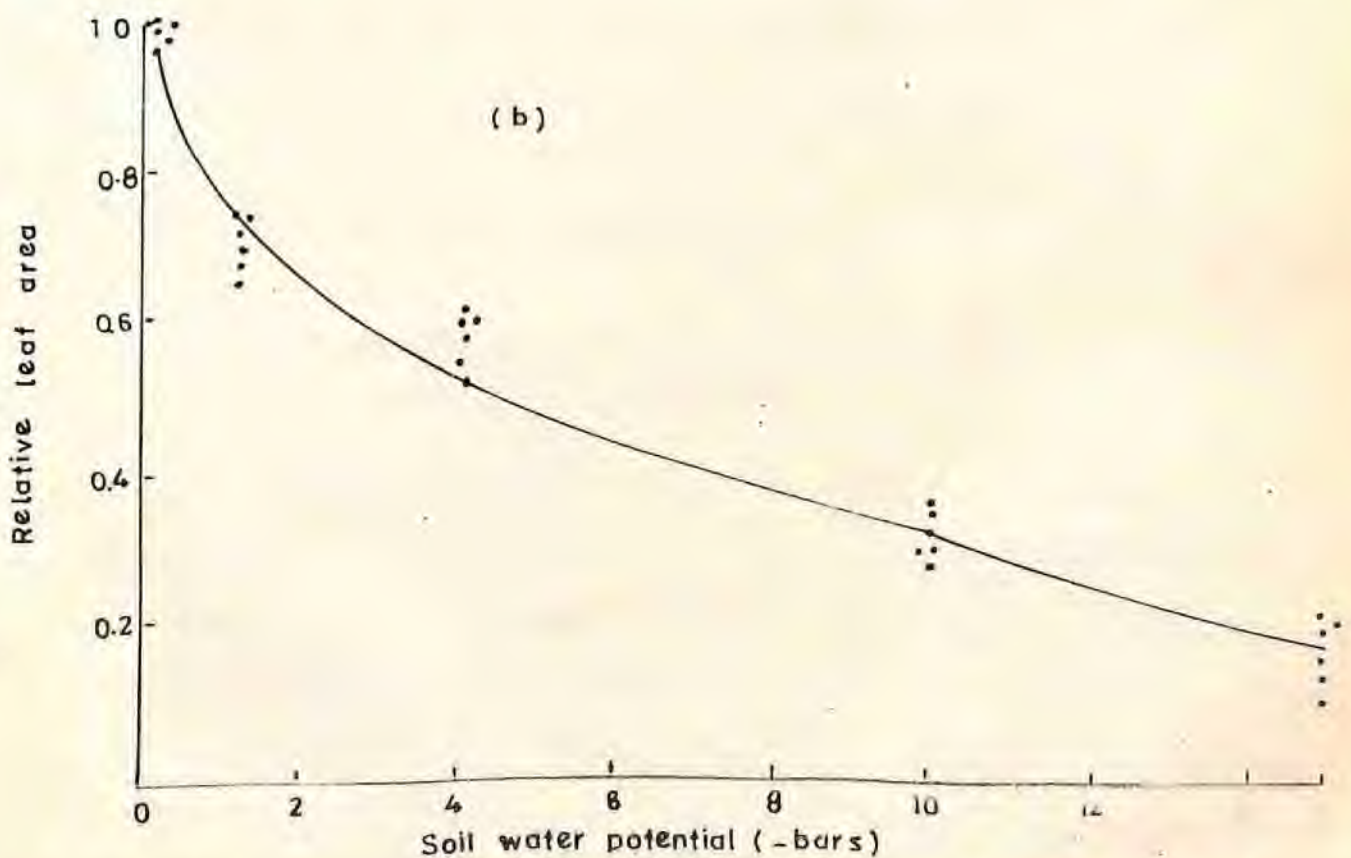
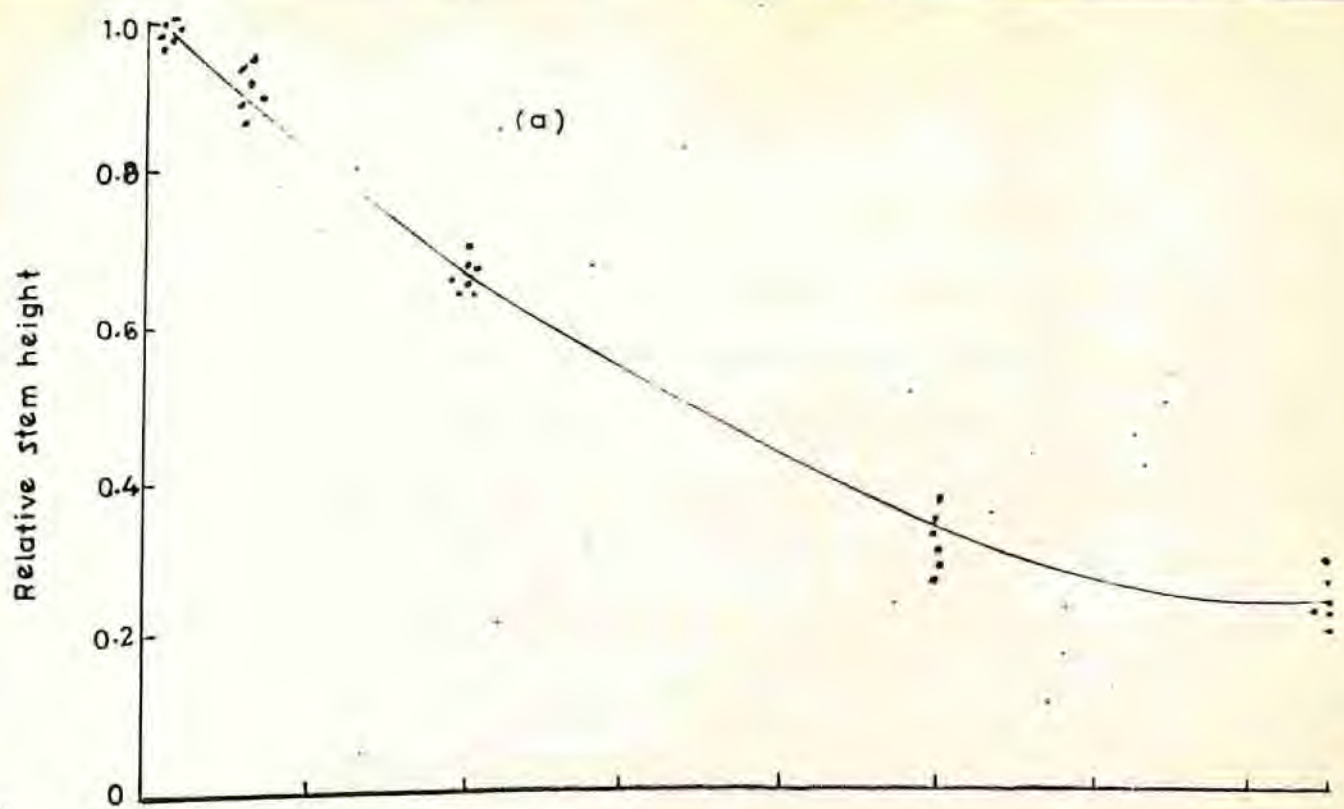


FIG. 6 - EFFECT OF SOIL WATER POTENTIAL ON (a) RELATIVE STEM HEIGHT & (b) RELATIVE LEAF AREA OF SOYBEAN PLANTS GROWN ON CLAY SOIL.

Relative leaf area (leaf area under stress conditions divided by the leaf area of plants grown at field capacity moisture content) has been plotted in Fig. 6(b). It is revealed that there was a sharp decline in green leaf area of soybean when SWP decreased from -0.33 to -4 bars. Further decrease in SWP from -4 to -15 bars resulted almost in linear decrease in green leaf area at a relatively slow rate.

Total number of green leaves under different treatments at different times were also recorded and the data have been presented in appendix 5. At any time maximum number of green leaves were recorded when SWP was maintained at -0.33 bars and decreased with decreasing SWP. After 42 days of sowing such decrease in total number of leaves per two plants due to decreasing SWP upto -1.2, -4, -10 and -15 bars was observed (Appendix 5) to be by 14.2, 25.5, 57.1 and 75.4 per cent respectively.

#### 4.2.2 Fresh and dry weight of soybean shoot in relation to soil water potential

The data on fresh and dry weight of soybean plants recorded at different time under different treatments have been given in appendix 7 and 8. The changes in relative fresh and dry weight of soybean plants due to change in SWP have been depicted in Fig. 7. It is observed from the data that maximum fresh shoot weight of soybean was recorded at

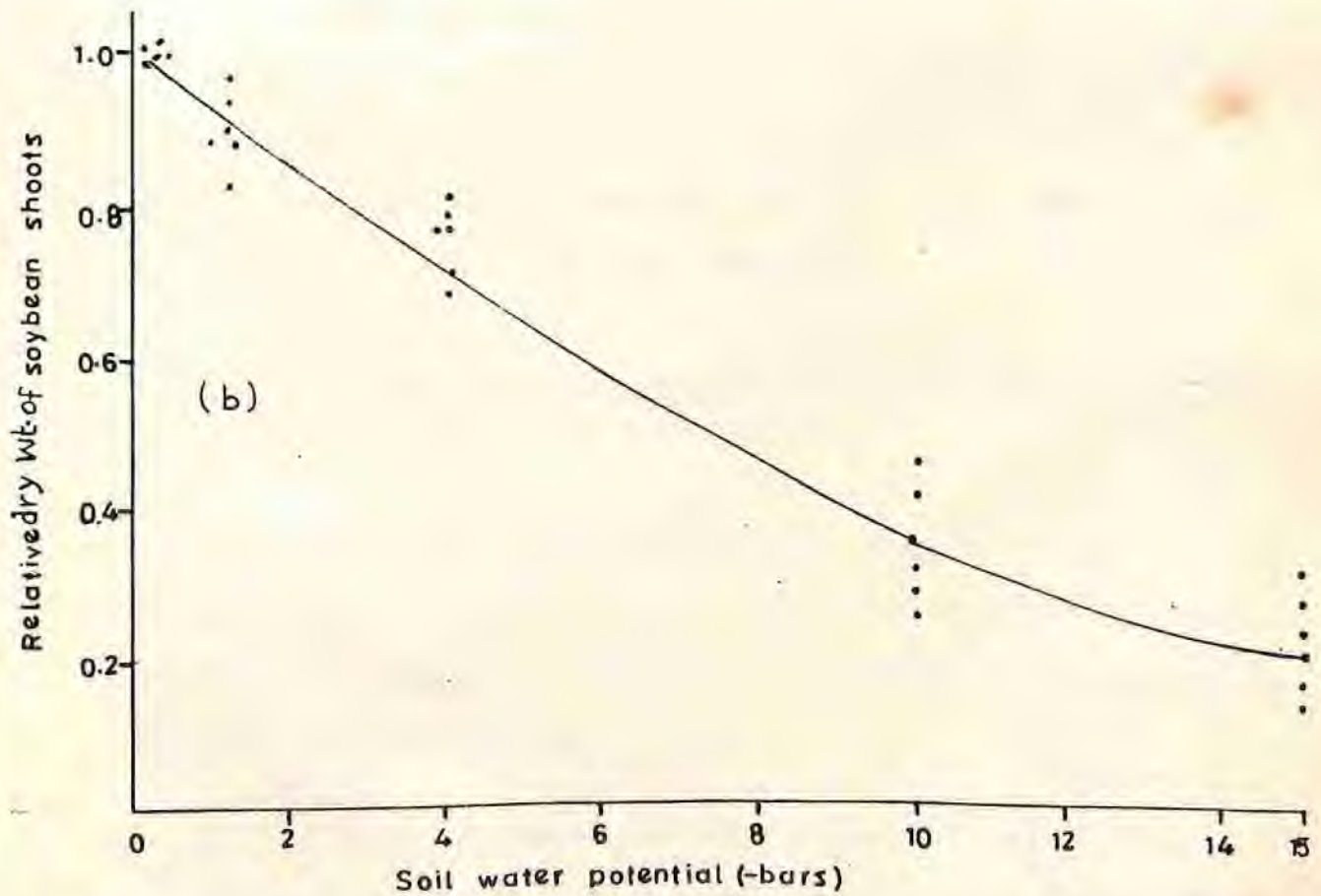
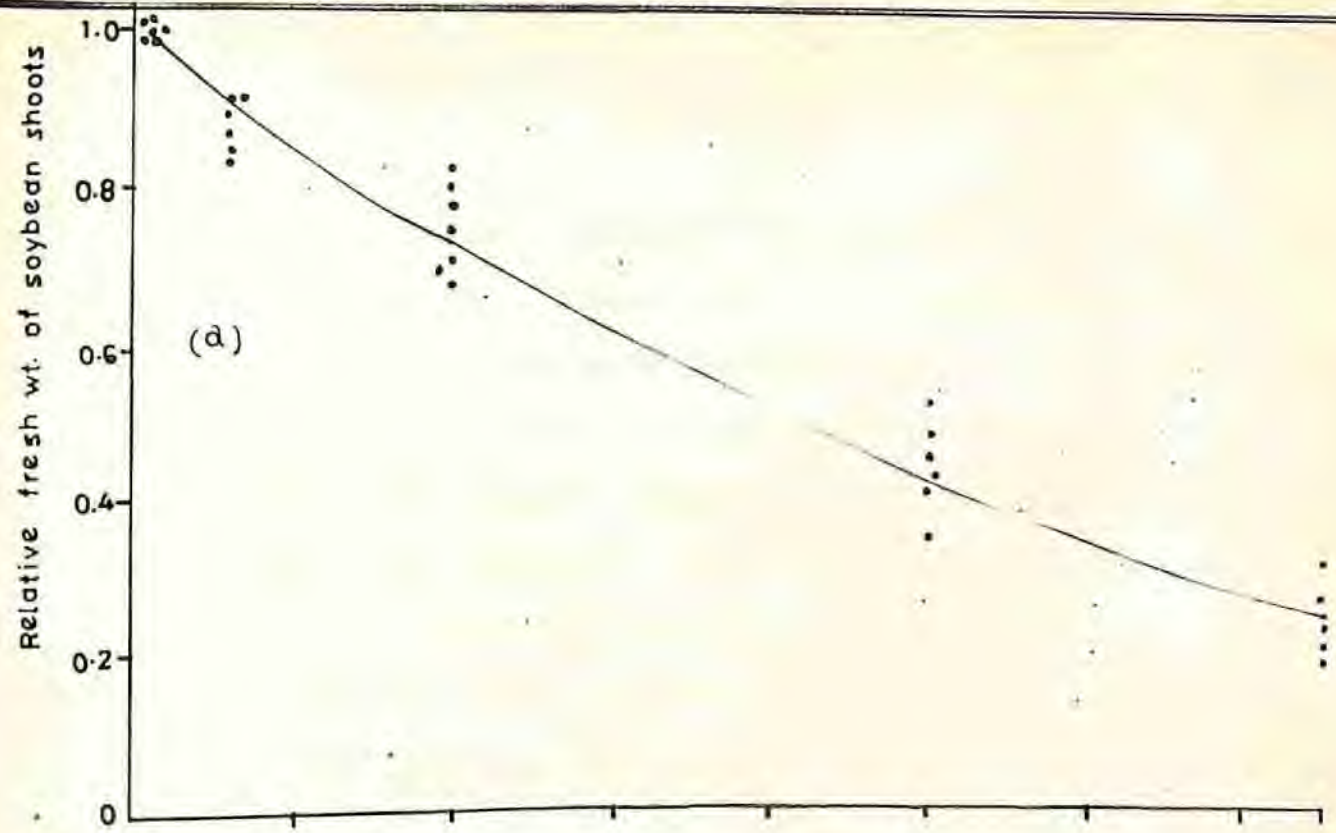


Fig. 7- INFLUENCE OF SOIL WATER POTENTIAL ON (a) RELATIVE FRESH Wt. & (b) RELATIVE DRY Wt OF SOYBEAN PLANTS GROWN ON CLAY SOIL

field capacity moisture conditions which decreased with decreasing SWP. There was a sharp decrease in fresh weight of soybean shoots due to decrease in SWP from -0.33 to -2 bars and further decrease in SWP from -2 bars to -15 bars caused a linear decrease in fresh weight of soybean shoot as indicated by relation between relative fresh weight of soybean shoot and SWP as shown in Fig. 7(a). Almost reduction of shoot weight upto 50 per cent of the recorded at field capacity moisture content was resulted at -8 bars SWP.

Fig. 7(b) presents the data on relative dry weight of soybean shoot as related to SWP. It is observed from the curved that maximum (100%) relative dry weight was observed at -0.33 bars SWP and decreased almost linearly with decreasing SWP upto -15 bars.

#### 4.2.3 Fresh and dry weight of soybean roots in relation to soil water potential

The data on fresh and dry weight of soybean roots as influenced by different levels of SWP in the range of -0.33 to -15 bars recorded at different times have been given in appendix 9 and 10.

It is evident from the data that decreasing SWP adversely affected root growth of soybean. Maximum root growth took place at field capacity moisture content and

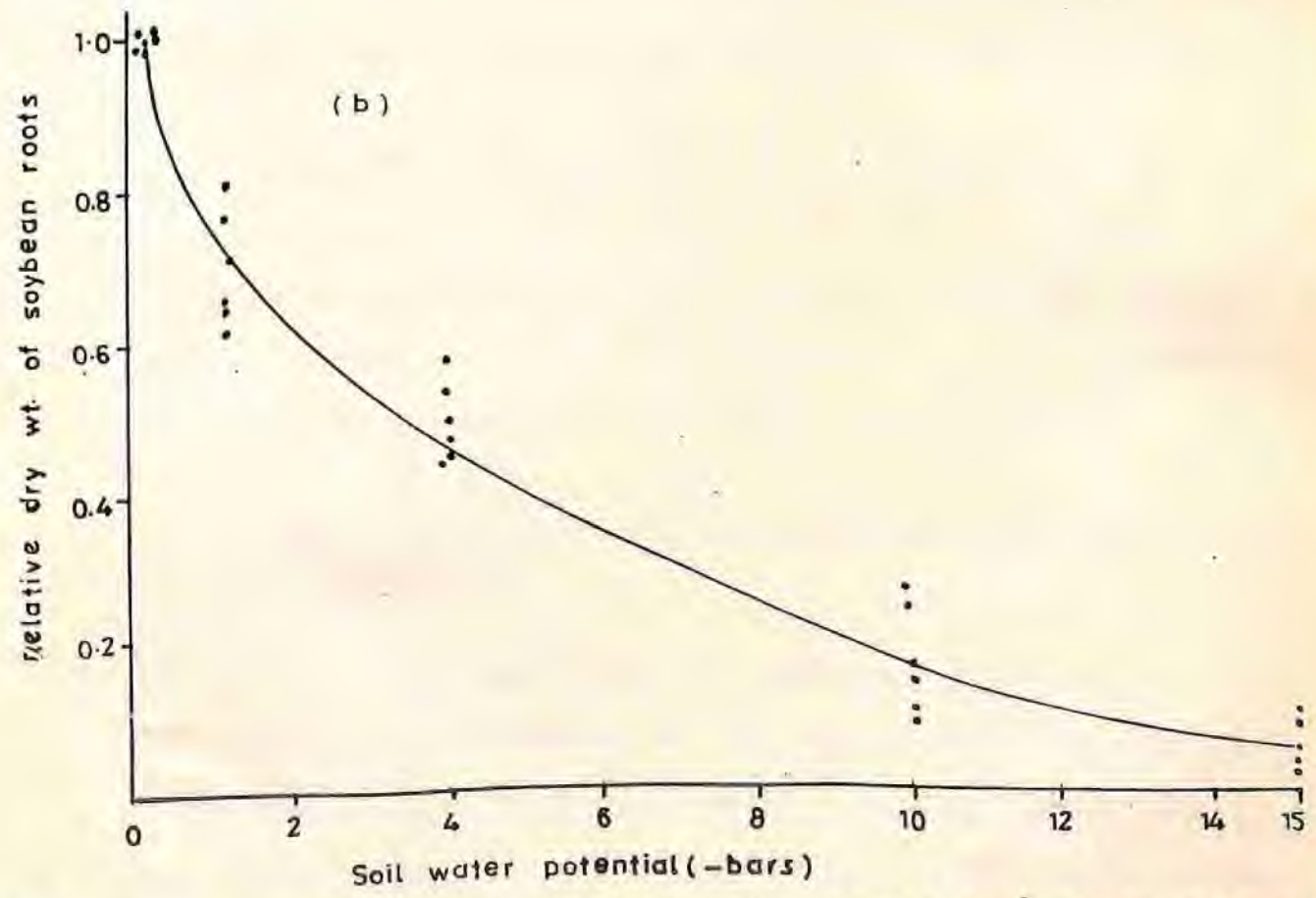
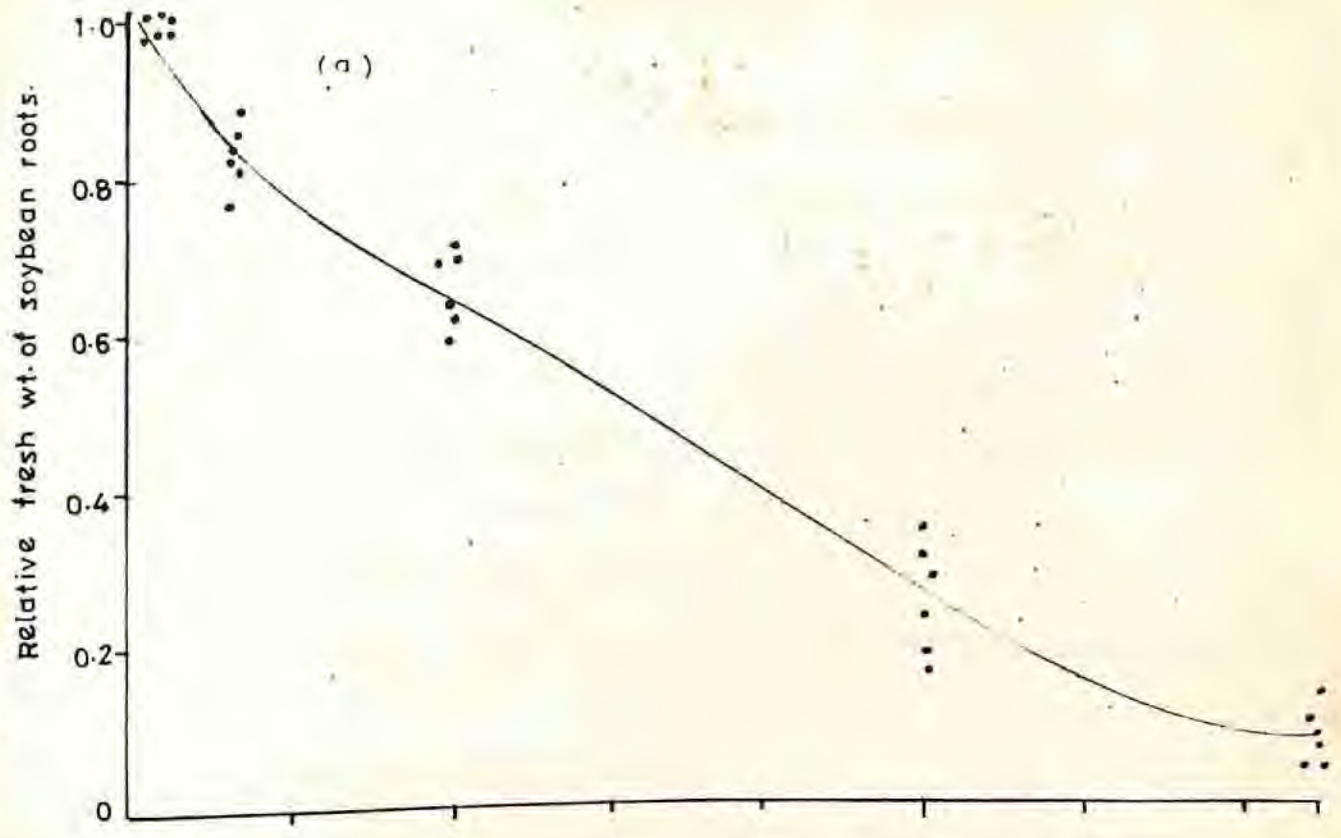


Fig. 8. EFFECT OF SOIL WATER POTENTIAL ON (a) RELATIVE FRESH WEIGHT & (b) RELATIVE DRY WEIGHT OF SOYBEAN ROOTS.

decreased gradually with decreasing SWP upto -10 bars. The decrease in SWP to -10 and -15 bars resulted very poor growth of soybean roots.

The relationship between soil water potential and root growth was assessed by computing relative fresh and dry weight of soybean roots (total weight of roots under moisture stress conditions divided by root weights recorded at field capacity moisture content) and the same have been depicted in Fig.8. As shown in Fig. 8 that maximum root growth of soybean (as reflected by fresh and dry weight at varying SWP values) took place at field capacity moisture content. Fresh weight of soybean roots decreased almost linearly with decreasing SWP in -0.33 to -15 bars (Fig.8 a).

The dry weight of soybean roots decreased sharply when SWP was decreased from -0.33 to -4 bars followed by a gradual decrease in -4 to -10 bars SWP. Further decrease in SWP beyond -10 to -15 bars resulted in only a marginal decrease in dry weight of soybean roots (Fig. 8 b).

#### 4.2.4 Effect of soil water potential on shoot/root ratio of soybean

The shoot/root ratio of soybean under different treatments was worked out on dry weight basis and the data have been presented in appendix 11 and depicted in Fig.9. The shoot/root ratio of soybean increased from about 2 to 3

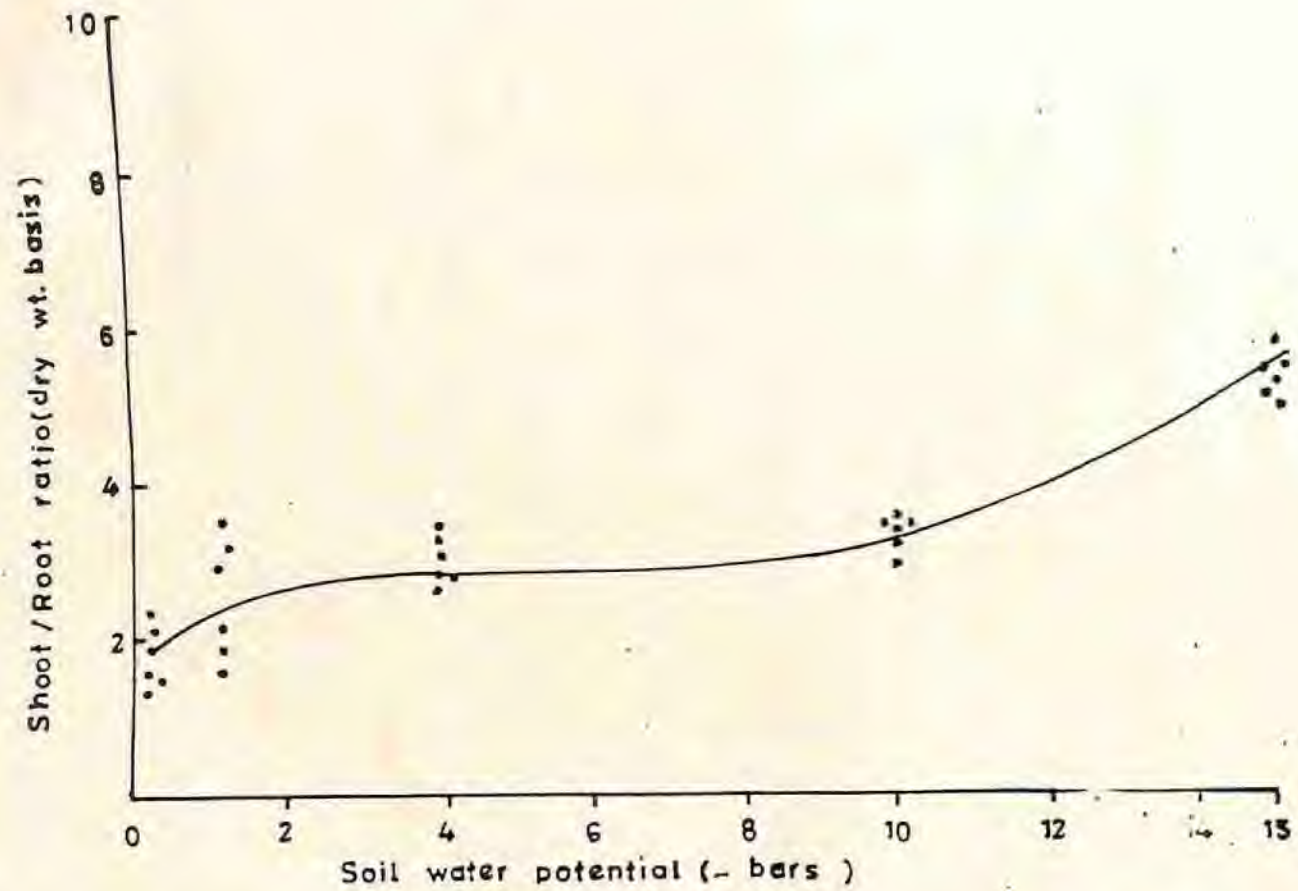


Fig.9. INFLUENCE OF SOIL WATER POTENTIAL ON SHOOT/ROOT RATIO OF SOYBEAN

with decreasing SWP from -0.33 to -4 bars. The decrease in SWP from -4 to -10 bars did not cause any change in shoot/root ratio as it remained about 3 throughout this range of SWP. Further decrease in SWP from -10 to -15 bars caused a considerable increase in shoot/root ratio from about 3.5 to 5.5 respectively at -10 and -15 bars SWP.

#### 4.2.5 Transpiration in relation to soil water potential

The transpiration of soybean during the vegetative growth period recorded at different intervals have been given in appendix 12 and depicted in Fig. 10(a). It is revealed from the data that transpiration rate of soybean at SWP of -0.33 bars ranged from 0.64 to 0.52 g/cm<sup>2</sup>/day and decreased with decreasing SWP. In general the transpiration rate decreased in all the treatments with the age of the plants. As is shown in Fig. 10(a) that there was a sharp decrease in transpiration rate of soybean with decrease in SWP from -0.33 to -4 bars. Further decrease in SWP from -4 to -10 bars caused a gradual decrease in transpiration rate only up to 28th day of sowing after that the transpiration rate were almost stabilized leading to a minimum value of 0.06 g/cm<sup>2</sup>/day at -15 bars SWP.

For establishing the relationship between transpiration and SWP, relative transpiration rate (transpiration rate under soil moisture stress conditions

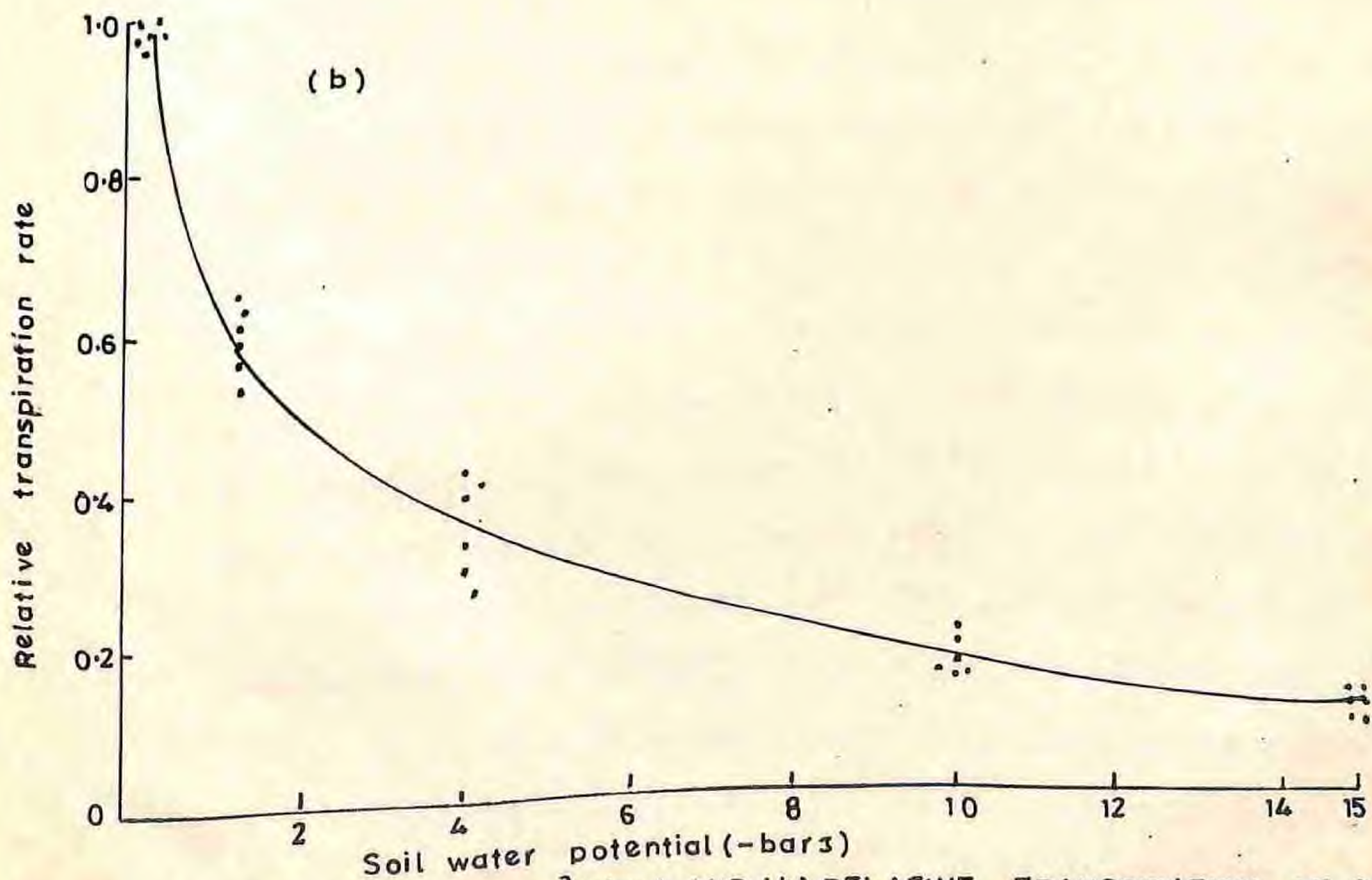
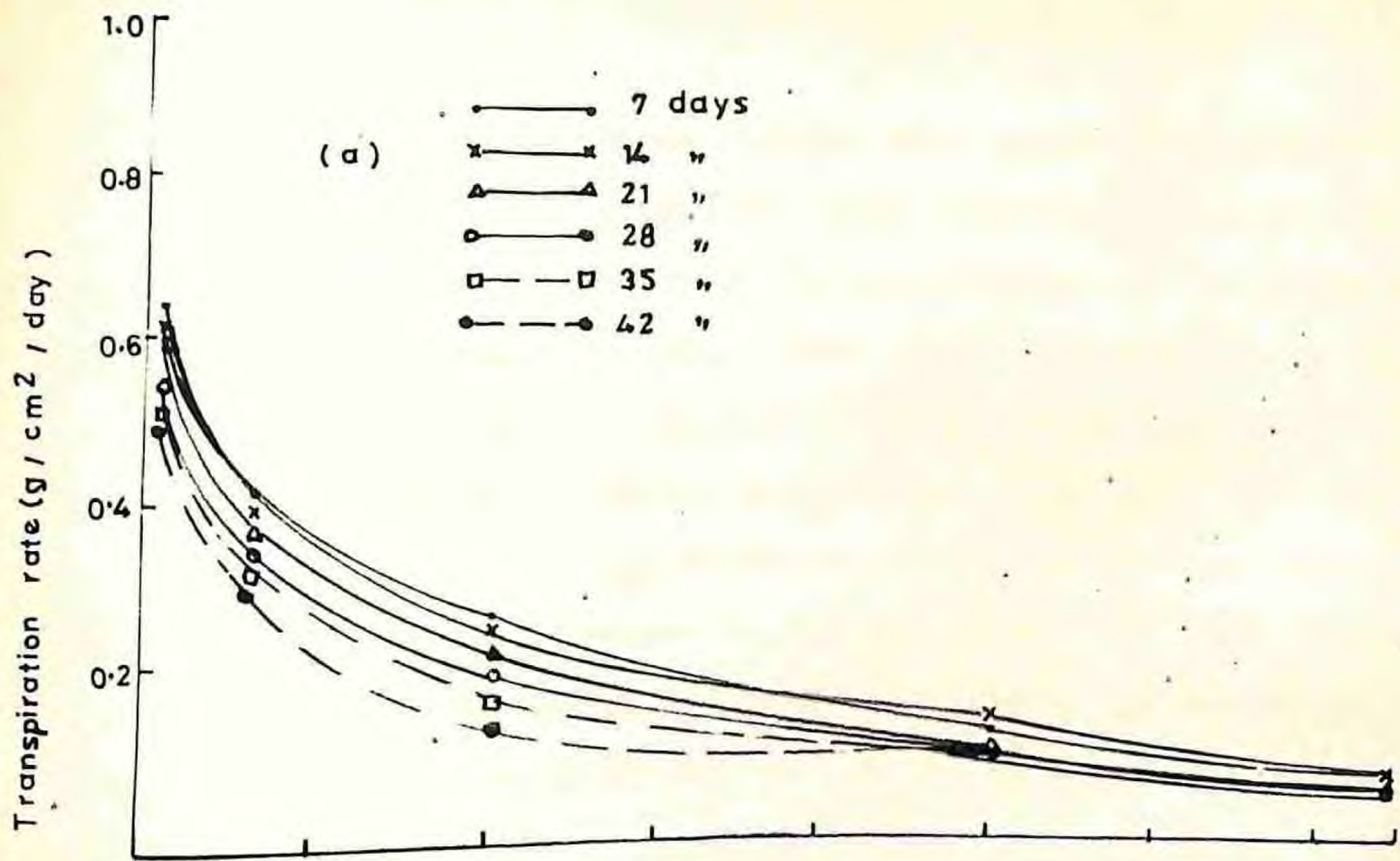


Fig.10. (a) TRANSPIRATION ( $g/cm^2/day$ ) AND (b) RELATIVE TRANSPIRATION OF SOYBEAN PLANTS ON CLAY SOIL UNDER DIFFERENT SOIL WATER POTENTIAL

divided by the transpiration rate recorded at field capacity moisture content) have been worked out and the data have been depicted in Fig. 10 (b). It is obvious from the curve in Fig. 10(b) that the decrease in SWP from -0.33 to -4 bars resulted in a sharp decline of relative transpiration rate from 1 to 0.35. In -4 to -10 bars SWP range, the decrease in relative transpiration rate per bar decrease in SWP was relatively less followed by only a marginal decrease in relative transpiration rate per bar decrease of SWP in -10 to -15 bars range.

### 4.3 NITROGEN FERTILIZATION

#### 4.3.1 Yield and its attributory characters

The data on the influence of different treatments on height of plants, number of pods/plant, fresh and dry weight of plants, number and weight of grain per 10 plants and test weight, grain and straw yield of soybean have been presented in table 6 and 7 respectively. It is evident from the data that the application of nitrogen in general caused a significant increase in plant height, fresh and dry weight of plants, grain number and weight of 10 plants as compared to control. The bearing of pods was also increased due to nitrogen fertilization but significant increase could be observed only due to treatment  $N_{20}(\frac{1}{2}U + \frac{1}{2}FYM)$ . It is also obvious that application of nitrogen at the rate of 20 kg/ha half through urea and half through FYM

Table 6 - Effect of different levels of nitrogen on height of the plant, number of pods/plant, fresh and dry weight of 10 plants, number and weight of grain/10 plants.

S.No.	Treatments	Average height of 10 plants	Average number of pods/plant	Weight of 10 plant (gm)		Number of grains/10 plants.	Weight of grain/10 plants (gm)
				Fresh weight	dry weight		
1.	N <sub>0</sub> (Control)	56.47	51.06	160.6	126.6	988.33	100.5
2.	N <sub>20</sub>	64.56	64.83	216.9	176.6	1137.00	127.1
3.	N <sub>10</sub>	64.56	55.80	253.2	209.9	1047.00	103.7
4.	N <sub>6.7</sub>	63.64	54.03	217.2	191.0	1044.67	103.6
5.	N <sub>10</sub> FYM	73.58	61.13	278.2	229.1	1117.33	121.3
6.	N <sub>16.7</sub>	66.76	56.47	246.0	208.2	1093.0	106.6
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	74.34	65.87	284.7	233.8	1281.67	188.8
8.	N <sub>20</sub> + Zn	67.27	65.10	227.4	193.0	1225.67	130.1
9.	N <sub>0</sub> farmer's control	60.24	41.40	202.7	164.5	748.00	77.5
S.E.m. $\pm$		1.68	4.88	14.07	15.10	73.34	7.47
C.D. 5%		5.02	14.62	42.17	45.27	219.89	22.38
C.D. 1%		6.92	N.S.	58.10	62.37	302.56	30.84
C.V.		4.41%	14.74%	10.5%	13.58%	11.78%	11.76%

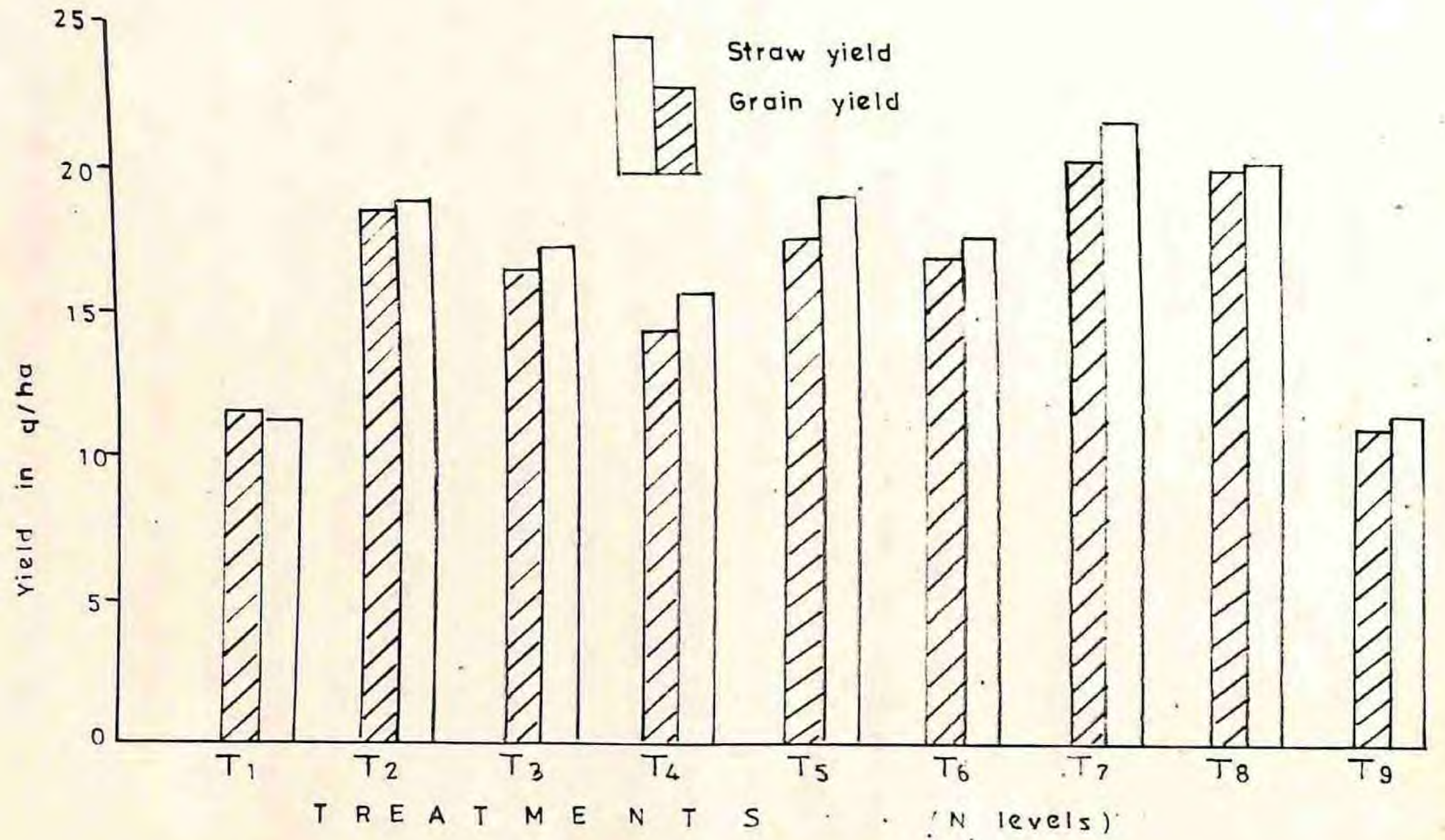


Fig.11 - AVERAGE GRAIN AND STRAW YIELD OF SOYBEAN (q/ha) AS INFLUENCED BY DIFFERENT LEVELS OF NITROGEN

gave maximum benefit followed by the 10 kg of N/ha through FYM. Decreasing levels of nitrogen applied through fertilizer caused a progressive decrease in all the growth characters in general.

The grain and straw yield of soybean as influenced by different treatments have been given in table-7 and Fig. 11. It is obvious from the data that highest grain yield (20.23 q/ha) was obtained due to application of 20 kg N/ha half through urea and half through FYM which was statistically significant over all the other treatments under consideration. Next in order were the treatments N<sub>20</sub> + Zn (19.03 q/ha grain yield) and N<sub>20</sub> (18.82 q/ha grain yield) treatments respectively as far as their effect on grain yields were concerned. These results indicated that application of zinc has given an additional advantage. It is also apparent from the results that decreasing the N levels from 20 kg/ha to lower side caused a progressive decrease in soybean grain yield also. The thousand grain weight and soybean straw yield also followed a trend very similar to grain yield.

#### 4.3.2 Chemical composition of soybean plants

Nutrient content in soybean grain and straw as affected by different treatments have been given in table 8 and 9. The nitrogen content in grain varied from 5.71% (No farmer's control) to 5.87% (N<sub>20</sub> + Zn). The

Table 7 - Effect of different levels of nitrogen on 1000 grain weight, grain on straw yield of soybean.

S.No. :	Treatments	: 1000 : grain : weight : (gm)	: Grain : yield : (q/ha)	: Straw : yield : (q/ha)
1.	N <sub>0</sub> (Control)	98.30	11.78	11.35
2.	N <sub>20</sub>	105.00	18.82	18.92
3.	N <sub>10</sub>	100.83	16.54	17.25
4.	N <sub>6.7</sub>	100.27	14.49	15.73
5.	N <sub>10</sub> FYM	104.37	17.55	18.94
6.	N <sub>16.7</sub>	102.40	16.92	17.58
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	111.76	20.23	21.65
8.	N <sub>20</sub> + Zn	111.43	19.03	19.14
9.	N <sub>0</sub> (Farmer's control)	98.17	11.03	11.62
S.E.m. $\pm$		0.93	0.31	0.67
C.D. 5%		2.79	0.94	2.01
C.V.		1.56%	3.35%	6.92%

differences in nitrogen content due to treatments T<sub>8</sub> (N<sub>20</sub>+ Zn), T<sub>7</sub> (N<sub>20</sub>( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM)), T<sub>5</sub> (N<sub>10</sub>FYM) and T<sub>2</sub> (N<sub>20</sub>), were statistically nonsignificant. It is also apparent that decreased levels of nitrogen application through urea down to 20 kg N/ha caused decreased N concentration in soybean grain. The nitrogen content in soybean grain under treatment, T<sub>5</sub> (N<sub>10</sub> FYM) was as good as was obtained due to application of 20 kg N/ha through urea (T<sub>2</sub>) alone.

Table 8 - N, P, K, Ca and Mg content of soybean grain as affected by different treatment.

S. NO.	Treatments	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)	Calcium content (%)	Magnesium content (%)
1.	N <sub>0</sub> (Control)	5.72	0.68	2.41	0.87	0.47
2.	N <sub>20</sub>	5.84	0.70	2.41	0.91	0.45
3.	N <sub>10</sub>	5.81	0.70	2.54	0.92	0.47
4.	N <sub>6.7</sub>	5.76	0.71	2.41	0.91	0.49
5.	N <sub>10</sub> FYM	5.83	0.70	2.67	0.96	0.45
6.	N <sub>16.7</sub>	5.81	0.71	2.47	0.88	0.50
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	5.84	0.70	2.47	0.91	0.50
8.	N <sub>20</sub> + Zn	5.87	0.68	2.34	0.91	0.48
9.	N (Farmer's control)	5.71	0.69	2.29	0.87	0.45
S.Em. $\pm$		0.01	0.06	0.08	0.02	0.008
C.D. 5%		0.03	N.S.	N.S.	N.S.	0.024
C.D. 1%		N.S.	N.S.	N.S.	N.S.	0.033
C.V.		0.31%	16.39%	5.85%	4.29%	2.915%

The phosphorus, potassium, calcium and magnesium content in soybean grain ranged from 0.68 to 0.71, 2.29 to 2.67, 0.87 to 0.96 and 0.45 to 0.50 per cent respectively. However the differences in the concentration of these nutrients in grain were statistically nonsignificant, except in magnesium content which differed significantly.

The nitrogen, phosphorus, calcium and magnesium content in soybean straw ranged from 1.81 to 2.08, 0.031 to 0.047, 2.08 to 2.41 and 0.41 to 0.46 per cent respectively and the differences were statistically significant. The potassium content in straw varied from 2.08% in control to 2.41% in T<sub>8</sub> (N<sub>20</sub> + Zn) being

Table 9 - N, P, K, Ca and Mg content of soybean plant straw as affected by different treatments.

S. NO.	Treatments	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)	Calcium content (%)	Magnesium content (%)
1.	N <sub>0</sub> control	1.86	0.033	0.08	0.82	0.44
2.	N <sub>20</sub>	2.00	0.047	2.34	0.76	0.42
3.	N <sub>10</sub>	1.93	0.046	2.21	0.78	0.45
4.	N <sub>6.7</sub>	1.90	0.047	2.08	0.84	0.44
5.	N <sub>10</sub> FYM	1.94	0.047	2.34	0.81	0.43
6.	N <sub>16.7</sub>	1.97	0.046	2.34	0.80	0.46
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	2.05	0.046	2.20	0.80	0.43
8.	N <sub>20</sub> + Zn	2.08	0.045	2.41	0.79	0.41
9.	N <sub>0</sub> (Farmer's control)	1.81	0.031	2.21	0.74	0.42
S.E.M. $\pm$		0.008	0.001	0.22	0.023	0.007
C.D. 5%		0.024	0.003	N.S.	0.071	0.023
C.D. 1%		0.033	0.004	N.S.	0.098	N.S.
C.V.		0.725%	4.63%	16.68%	5.19%	3.04%

statistically at par in all the treatments. The nitrogen content in soybean straw due to different levels and source of nitrogen was significantly more as compared to controls. The treatments T<sub>8</sub> (N<sub>20</sub> + Zn) and T<sub>7</sub> (N<sub>20</sub>( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM)) were statistically at par in this respect while N content in treatments T<sub>2</sub> (N<sub>20</sub>), T<sub>3</sub> (N<sub>10</sub>), T<sub>5</sub>(N<sub>10</sub> FYM) and T<sub>6</sub> (N<sub>16.7</sub>) was observed to be significantly less.

#### 4.3.3 Uptake of nutrients

The uptake of nutrients by soybean grain, straw and total uptake as influenced by different treatments have been presented in table 10, 11 and 12 respectively. As is revealed from the data that the uptake of nitrogen, phosphorus, potassium, calcium and magnesium by grain and straw was significantly affected by different levels of nitrogen and source. The N uptake by soybean grain varied from 63.07 kg/ha to 118.27 kg/ha in farmer's control and N<sub>20</sub> ( $\frac{1}{2}$  urea +  $\frac{1}{2}$  FYM) treatments respectively. The uptake of N due to N<sub>20</sub> ( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM) was significantly more than due to any of the treatments under consideration. Application of Zn alongwith N<sub>20</sub> caused only about 1.73 kg N/ha more uptake than only 20 kg N/ha (T<sub>2</sub>) however, this difference was nonsignificant. Decreasing levels of N applied through urea down to 20 kg N/ha caused a progressive decrease in N uptake by grain to a significant level. The differences in N uptake due to N<sub>10</sub>, N<sub>16.7</sub> and N<sub>10</sub> FYM treatments were nonsignificant but further decrease

in N application to N<sub>6.7</sub> caused a significant reduction in nitrogen uptake (83.56 kg N/ha).

Application of different rates of N through urea and FYM caused the significant differences in uptake of P, K, Ca and Mg nutrients by soybean grain. The P and K uptake

Table 10 - Uptake of N, P, K, Ca and Mg by soybean grain as affected by different treatments.

S. NO.	Treatments	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)	Calcium uptake (kg/ha)	Magnesium uptake (kg/ha)
1.	N <sub>0</sub> (Control)	67.37	8.06	28.33	10.24	5.52
2.	N <sub>20</sub>	110.04	13.27	45.31	17.08	8.53
3.	N <sub>10</sub>	96.13	11.70	39.74	15.24	7.82
4.	N <sub>6.7</sub>	83.56	10.30	34.87	13.34	7.10
5.	N <sub>10</sub> FYM	101.37	12.43	46.79	16.79	7.84
6.	N <sub>16.7</sub>	98.29	12.02	41.83	14.88	8.39
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	118.27	14.26	50.10	18.40	10.05
8.	N <sub>20</sub> + Zn	111.77	13.01	44.53	17.25	9.12
9.	N <sub>0</sub> (Farmer's control)	63.07	7.61	25.02	9.65	4.93
	S.Em. $\pm$	1.83	0.19	1.08	0.47	0.12
	C.D. 5%	5.48	0.59	3.25	1.42	0.38
	C.D. 1%	7.56	0.82	4.47	1.95	0.53
	C.V.	3.35%	3.01%	4.74%	5.57%	2.88%

ranged 7.61 to 14.26 kg/ha and 25.02 to 50.10 kg/ha respectively in treatments T<sub>9</sub> (N<sub>0</sub>, farmer's control) and T<sub>7</sub> (N<sub>20</sub> ( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM)). Similarly the uptake of Ca and Mg varied from 9.65 to 18.40 kg/ha and 4.93 to 10.05 kg/ha respectively under the same treatments. Decreased levels of N in the range of 20 to 6.7 kg/ha showed a decreasing trend in the uptake of the these nutrients by soybean grain.

The removal of N, P and K by soybean straw (Table-11) ranged in between 20.98 to 44.44 kg/ha, 0.35 to 0.99 kg/ha, and 23.56 to 48.27 kg/ha respectively, highest being due to application of N<sub>20</sub> alongwith 25 kg of ZnSO<sub>4</sub>/ha. Similarly the uptake of Ca and Mg varied from 8.59 to 17.22 kg/ha and 4.95 to 9.41 kg/ha respectively in T<sub>9</sub> (N<sub>0</sub>, farmer's control) and T<sub>7</sub> (N<sub>20</sub> ( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM) treatments. The trend in uptake of all these nutrients by soybean straw was decreasing with decreasing rate of N application. The difference in uptake were observed to be statistically significant.

(contd. 82)

Table 11 - Uptake of N, P, K, Ca and Mg by soybean straw as affected by different treatments.

S. NO.	Treatments	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)	Calcium uptake (kg/ha)	Magnesium uptake (kg/ha)
1.	N <sub>0</sub> (Control)	21.16	0.38	23.56	9.36	4.99
2.	N <sub>20</sub>	38.09	0.90	44.79	14.45	8.13
3.	N <sub>10</sub>	33.39	0.79	37.81	13.50	8.37
4.	N <sub>6.7</sub>	29.96	0.73	32.78	13.14	6.93
5.	N <sub>10</sub> FYM	36.76	0.89	44.16	15.36	8.19
6.	N <sub>16.7</sub>	34.70	0.80	40.50	14.03	7.87
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	44.41	0.99	48.27	17.22	9.41
8.	N <sub>20</sub> + Zn	39.92	0.86	46.41	15.09	7.90
9.	N <sub>0</sub> (Farmer's control)	20.98	0.35	25.95	8.59	4.95
S. Em. $\pm$		0.52	0.03	4.14	0.65	0.40
C.D. 5%		1.58	0.10	12.41	1.96	1.20
C.D. 1%		2.17	0.15	17.10	2.70	1.65
C.V.		2.77%	8.42%	18.74%	8.44%	9.37%

The total uptake of N, P, K, Ca and Mg by soybean grain and straw have been summarised in table-12. The total uptake obeyed similar trend as that shown by grain and straw independently. The differences in uptake of these nutrients due to N<sub>6.7</sub> and N<sub>10</sub>, N<sub>16.7</sub> and N<sub>20</sub> were relatively narrow particularly in case of P, Ca and Mg uptake by soybean straw.

Table 12 - Total uptake of nutrients by soybean.

S. NO.	Treatments	Total nitrogen uptake (kg/ha)	Total phosphorus uptake (kg/ha)	Total potassium uptake (kg/ha)	Total calcium uptake (kg/ha)	Total Magnesium uptake (kg/ha)
1.	N <sub>0</sub> (Control)	88.53	8.44	51.89	19.60	10.51
2.	N <sub>20</sub>	148.13	14.17	90.10	31.53	16.66
3.	N <sub>10</sub>	129.52	12.49	77.55	28.74	16.19
4.	N <sub>6.7</sub>	113.52	11.03	67.65	26.48	14.03
5.	N <sub>10</sub> FYM	138.13	13.32	90.95	32.15	16.03
6.	N <sub>16.7</sub>	132.99	12.82	82.33	28.91	16.26
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	162.68	15.25	98.37	35.62	19.46
8.	N <sub>20</sub> + Zn	151.69	13.87	90.94	32.34	17.02
9.	N <sub>0</sub> (Farmer's control)	84.05	7.96	50.97	18.24	9.88

#### 4.3.4 Biochemical composition of soybean grain

Protein and oil content and their estimated yield as influenced by different treatments have been presented in table-13. A perusal of data presented in table-13 indicated that application of nitrogen significantly increased the protein content and thus the estimated protein yield. The maximum protein content of (36.71%) was recorded in treatment T<sub>8</sub> (N<sub>20</sub>+Zn) which was significantly higher than all the other treatments under consideration. The protein per cent at the same level of nitrogen i.e. N<sub>20</sub>(T<sub>2</sub>) was significantly less (36.52%) indicating that

application of zinc helped in increasing the protein content in soybean grain. Though the decreasing levels of nitrogen caused a progressive decrease in protein content but the differences due to T<sub>3</sub> (N<sub>10</sub>), T<sub>6</sub> (N<sub>16.7</sub>) and T<sub>5</sub> (N<sub>10</sub>FYM) were nonsignificant.

The estimated protein yield in soybean grain was also significantly increased due to application of nitrogen supplied by either source. The maximum protein yield of (7.39 q/ha) was recorded due to N<sub>20</sub>( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM) which was significantly more than rest of the treatments followed by T<sub>8</sub> ( N<sub>20</sub> + Zn) which gave 6.98 q/ha protein yield. The protein yield obtained due to treatment N<sub>20</sub>(6.87 q/ha) was statistically at par with N<sub>20</sub>+Zn. Decreased level of nitrogen given through urea caused decreased estimated protein yield. These results also indicated (Table-13) that FYM proved to be better than the urea as far as the protein yield was concerned.

Oil content of soybean grain decreased significantly due to application of nitrogen. It varied from 20.31% under farmer's control i.e. N<sub>0</sub> to 19.60% in N<sub>20</sub> + Zn. The differences in oil content under treatments N<sub>20</sub>, N<sub>10</sub>, N<sub>10</sub>FYM and N<sub>16.7</sub> were only marginal and statistically nonsignificant. As far as the estimated oil yield was concerned, it was significantly increased due to application of nitrogen and the trend was observed to be different from oil content data because of interacting effect of soybean

Table 13 - Protein, oil content in soybean and their estimated yield as influenced by different treatments.

S. NO.	Treatments	Protein content (%)	Protein yield (g/ha)	Oil content (%)	Oil yield (g/ha)
1.	N <sub>0</sub> (Control)	35.77	4.21	20.30	2.39
2.	N <sub>20</sub>	36.52	6.87	20.12	3.78
3.	N <sub>10</sub>	36.31	6.00	20.14	3.32
4.	N <sub>6.7</sub>	36.02	5.22	20.24	2.93
5.	N <sub>10</sub> FYM	36.44	6.39	20.13	3.53
6.	N <sub>16.7</sub>	36.31	6.14	20.13	3.40
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	36.52	7.39	19.63	3.97
8.	N <sub>20</sub> + Zn	36.71	6.98	19.60	3.72
9.	N <sub>0</sub> (Farmer's control)	35.68	3.94	20.31	2.24
S.E.m. $\pm$		0.06	0.11	0.01	0.06
C.D. 5%		0.18	0.34	0.02	0.19
C.D. 1%		0.26	0.47	0.03	0.26
C.V.		0.30%	0.37%	0.06%	3.43%

grain yield. The estimated oil yield ranged in between 2.24 to 3.97 g/ha respectively under N<sub>0</sub> (Farmer's control) and N<sub>20</sub>( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM) treatments. Decreased levels of nitrogen showed a decreasing trend in estimated oil yield.

4.3.5 Relationship between different nutrients and biochemical parameters

Correlations of different nutrients with protein and oil content of soybean (JS 72-44) were worked out and have been given in table-14. There existed significant positive

Table 14 - Correlation coefficients between different constituents of soybean grain.

S.No.	Fraction	r value
1.	Nitrogen Vs Protein	+ 0.999 <sup>++</sup>
2.	Phosphorus Vs Protein	+ 0.274 N.S.
3.	Potassium Vs Protein	+ 0.354 N.S.
4.	Calcium Vs Protein	+ 0.614 N.S.
5.	Magnesium Vs Protein	+ 0.206 N.S.
6.	Nitrogen Vs Oil	- 0.769 <sup>+</sup>
7.	Phosphorus Vs Oil	+ 0.127 N.S.
8.	Potassium Vs Oil	+ 0.297 N.S.
9.	Calcium Vs Oil	- 0.282 N.S.
10.	Magnesium Vs Oil	- 0.348 N.S.
11.	Protein Vs Oil	- 0.776 <sup>+</sup>

Table value of r for 7 d.f. at 5% = 0.666

Table value of r for 7 d.f. at 1% = 0.797

++ = Highly significant

+ = Significant

N.S. = Nonsignificant.

correlation between nitrogen and protein ( $r = 0.999^{++}$ ) content of grain as expected. The protein content and phosphorus, potassium, calcium and magnesium were also positively correlated but the values were statistically nonsignificant. There existed a significant negative correlation ( $r = -0.769^+$ ) between oil and nitrogen content of soybean. Similarly significant negative correlation ( $r = -0.776^+$ ) between protein and oil content was observed. Oil content versus phosphorus and potassium were positively correlated, relationship being statistically nonsignificant. The relationship between oil content and calcium and magnesium was negative as represented by nonsignificant correlation values between them (Table 14).

#### 4.3.6 Balance sheet of available nitrogen in soil

The available nitrogen content in soil was determined for 0-15 cm and 15-30 cm layers before sowing and after harvest of the crop. The changes in available soil nitrogen brought about due to different treatments after harvest of the crop were found to be statistically significant. A balance sheet of available nitrogen in soil has been prepared for both the soil layers and data have been presented in table 15 and 16 respectively. It is revealed from the data (Table 15) that there was a net gain of nitrogen in 0-15 cm soil layer ranging from 1.90 to 23.20 kg/ha in treatment N<sub>0</sub> (Farmer's control) and N<sub>20</sub>+ Zn respectively. A net gain of available nitrogen to the tune 18.63, 18.30, 15.50, 8.93, 8.77, 5.07

Table 15 - Balance sheet of available nitrogen under different treatments based on 0-15 cm deep soil layer.

S. NO.	Treatments	Before sowing (kg/ha)	Added through fertilizer (kg/ha)	Total (kg/ha)	After harvest (kg/ha)	Net grain/loss (kg/ha)
1.	N <sub>0</sub> (Control)	178.40	0.00	178.40	180.90	+ 2.50
2.	N <sub>20</sub>	180.20	20.00	200.20	218.50	+18.30
3.	N <sub>10</sub>	179.60	10.00	189.60	198.37	+ 8.77
4.	N <sub>6.7</sub>	179.60	6.70	186.30	191.37	+ 5.07
5.	N <sub>10</sub> FYM	181.30	10.00	191.30	200.23	+ 8.93
6.	N <sub>16.7</sub>	180.90	16.70	197.60	213.10	+15.50
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	183.00	20.00	203.00	221.63	+18.63
8.	N <sub>20</sub> + Zn	178.80	20.00	198.80	222.00	+22.20
9.	N <sub>0</sub> (Farmer's control)	178.20	0.00	178.20	180.17	+ 1.90
S.E.m. $\pm$		1.18		5.86		
C.D. 5%		N.S.		17.57		
C.D. 1%		N.S.		24.21		
C.V.		1.13%		5.00%		

and 2.50 kg/ha was recorded respectively due to treatments N<sub>20</sub>( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM), N<sub>20</sub>, N<sub>16.7</sub>, N<sub>10</sub><sup>FYM</sup>, N<sub>10</sub>, N<sub>6.7</sub> and N<sub>0</sub>(Control).

Balance sheet of available nitrogen in 15-30 cm soil layer (Table 16) indicated a net depletion of 1.27 and 1.43 kg/ha of nitrogen in treatments N<sub>0</sub>(Control) and N<sub>0</sub>(farmer's

Table 16 - Balance sheet of available nitrogen as influence by different treatments based on 15 to 30 cm soil layer.

S. NO.	Treatments	Before sowing (kg/ha)	Added through fertilizer (kg/ha)	Total (kg/ha)	After harvest (kg/ha)	Net gain/loss (kg/ha)
1.	N <sub>0</sub> (Control)	176.40	0.00	176.40	175.13	-1.27
2.	N <sub>20</sub>	178.20	20.00	198.20	216.13	+17.93
3.	N <sub>10</sub>	177.60	10.00	187.60	194.27	+ 6.33
4.	N <sub>6.7</sub>	177.60	6.70	184.30	187.37	+ 3.07
5.	N <sub>10</sub> FYM	179.30	10.00	189.30	196.63	+ 7.33
6.	N <sub>16.7</sub>	178.90	16.70	195.60	210.40	+14.80
7.	N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	181.00	20.00	201.00	219.33	+18.33
8.	N <sub>20</sub> + Zn	176.80	20.00	196.80	220.30	+23.50
9.	N <sub>0</sub> (Farmer's control)	176.20	0.00	176.20	174.77	- 1.43
	S.E.M. $\pm$		1.11		5.61	
	C.D. 5%		N.S.		16.83	
	C.D. 1%		N.S.		23.19	
	C.V.		1.08%		4.88%	

control) where no fertilizer from any of the source was applied. Other treatments witnessed a net gain of available nitrogen in this soil layer highest being 23.50 kg/ha in N<sub>20</sub>+ Zn treatment followed by 18.33 and 17.93 kg/ha nitrogen in N<sub>20</sub>( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM) and N respectively. Decreased rates of nitrogen application caused net gain of nitrogen at progressively decreasing rates.

Available phosphorus, potassium, calcium and magnesium in 0-15 and 15-30 cm layer were also determined after harvest of the crop and the data have been given in Appendix 20 and 21. The changes in available P, K, Ca and Mg as affected by different treatments were observed to be nonsignificant.

INTRODUCTION

The present study is concerned with the investigation of the effect of the concentration of the reactants on the rate of the reaction.

EXPERIMENTAL PROCEDURE

The rate of reaction was measured by the change in the volume of gas evolved at different concentrations of the reactants. The reaction was carried out in a closed system at constant temperature. The volume of gas evolved was measured at regular intervals of time. The rate of reaction was calculated from the slope of the graph of volume of gas evolved versus time.

DISCUSSION

The results of the experiment show that the rate of reaction increases with the increase in the concentration of the reactants. This is because the number of molecules per unit volume increases with the increase in concentration, and hence the frequency of collisions between the molecules increases. The rate of reaction is directly proportional to the concentration of the reactants. The order of reaction with respect to the concentration of the reactants was found to be one. The rate of reaction is also affected by the temperature of the reaction. The rate of reaction increases with the increase in temperature. This is because the molecules possess more kinetic energy at higher temperature and hence the frequency of collisions between the molecules increases. The rate of reaction is also affected by the presence of a catalyst. A catalyst increases the rate of reaction by providing an alternative path for the reaction with a lower activation energy.

## DISCUSSION

The experimental results, as presented in previous chapter have been discussed with their probable reasoning in the present chapter.

### 5.1 SEEDLING EMERGENCE STUDIES :

5.1.1 The data presented in table 2 and Fig. 4 indicated maximum and early emergence of soybean took place at field capacity moisture content which progressively delayed and decreased with decreasing SWP. It is evident from the data that the final seedling emergence of soybean decreased from 98.10% to only 65% as the SWP decreased from -0.33 to -5 bars which may be considered as satisfactory emergence. Further decrease in SWP beyond -5 to -15 bars caused a marked reduction and delay in seedling emergence attributable to lesser water availability to the seed from its immediate surrounding. The rate of soil water movement would be too slow to supply sufficient moisture to the seed for its germination at relatively low SWP as reported by Hunter and Erickson (1952), Khan and Varade (1976), Rao and Gupta (1976). A progressive decrease in seedling emergence with decreasing SWP for a number of crops has also been reported by Collis George and Sands (1962), Todmar and Hillel (1969), Jensen (1971), Singh (1983), Sharma (1984). Thus it can

be inferred from foregoing discussion that for obtaining satisfactory emergence of soybean soil moisture stress beyond -5 bars should be avoided.

The data presented in Table-2 revealed that maximum final emergence rate index (ERI) was recorded at field capacity moisture content (-0.33 bars SWP) and decreased progressively at slow rate upto -5 bars SWP and further decrease in SWP upto -15 bars caused a marked reduction in ERI leading to a minimum value of 10.15 at -15 bars SWP which again indicated that SWP less than -5 bars should be avoided for achieving satisfactory emergence rate. The decrease in ERI with decreasing SWP is attributed to decreased water availability for soybean seeds. Similar results have been reported by Singh (1983), Sharma (1984) for safflower and barley crops respectively.

5.1.2 The data on plumule and radicle growth of soybean as affected by different treatments have been presented in Tables 3 and 4. It is revealed that maximum plumule and radicle growth was observed at -0.33 bars SWP and decreased significantly with decreasing SWP upto -15 bars and a highly significant correlation between final plumule length and SWP in -0.33 to -15 bars range was obtained. The maximum

plumule length of 160.8 mm was recorded after 168 hours of sowing at -0.33 bars SWP which decreased to 35.5 mm at -15 bars SWP. Similarly radicle length recorded after 168 hours of sowing was 150.0 at -0.33 bars SWP and decreased to 30.4 mm at -15 bars SWP. The reduction in plumule and radicle elongation with decreasing SWP may be attributed to limiting water supply due to drastic reduction in capillary conductivity with decreasing SWP. Hence the changes in free energy and capacity to transport water were responsible for reduction in plumule and radicle growth. Similar results on plumule and radicle elongation of different crops as affected by decreasing SWP have been reported earlier by Taylor and Ratliff (1969), Gupta and Singh (1975), Singh (1983), Sharma (1984). As almost 50% reduction in radicle and plumule growth of soybean took place upto -3 bars SWP, therefore it may concluded that a soil water potential less than -3 bars would be too hazardous for seedling growth of soybean.

**5.1.3** The results on the relative emergence, plumule and radicle growth of soybean have been presented in table 5 and Fig. 5. These results support the conclusions which are drawn in 5.1.1 and 5.1.2.

5.2 GROWTH AND TRANSPIRATION OF SOYBEAN IN RELATION TO SOIL WATER POTENTIAL

5.2.1 The data on average plant height and green leaf area have been presented in appendix 4 and 6. Relative stem height and leaf area of soybean in relation to SWP have been depicted in Fig. 6. It is revealed that relative plant height decreased almost linearly from 1.00 to 0.35 as SWP decreased from -0.33 to -10 bars. Further decline in SWP -10 to -15 bars caused only marginal decrease from 0.35 to 0.25. Almost linear decrease in relative plant height in -0.33 to -10 bars SWP range indicated shoot elongation at decreasing rate and marginal decrease in relative plant height in -10 to -15 bars SWP range indicated cessation of soybean shoot elongation. A sharp decline in relative green leaf area with decreasing SWP from -0.33 to -4 bars and followed by linear decrease at a relatively slow rate in -4 to -15 bars SWP range may be attributed to decreased water availability to soybean plants under prevailing atmospheric conditions which inhibited the normal physiological activity. Blanchet <sup>et al</sup> (1977), Blanchet and Gelfi (1978), Bunce (1978) and Shivakumar and Shaw (1978) also reported that leaf area of soybean decreased with increasing water stress in soybean. Wien et al. (1979)

observed reduction in main stem length due to moisture stress in cowpea and soybean. Huck et al. (1981) also reported similar results for leaf size and internode length of soybean.

The data on total number of green leaves under different treatments are presented in appendix 5. It is revealed that maximum number of green leaves were observed when SWP was maintained at -0.33 bars and decreased with decreasing SWP. Vendeland et al. (1980) observed that the rate of leaf production was very sensitive to water stress at all stages of vegetative development of the soybean plant, being reduced to nearly no growth under severe stress.

5.2.2 Fig. 7 shows the relative fresh and dry weight of soybean shoot as affected by decreasing SWP in -0.33 to -15 bars. It is observed that the maximum relative fresh and dry weight of shoots was recorded at field capacity moisture content. This was possible due to the reason that there was maximum water availability to plants at -0.33 bars SWP and plant leaves were turgid and fully developed as visually observed. There was a sharp decrease in fresh weight of soybean shoots due to decrease in SWP from -0.33 to -2 bars and further decrease in SWP from -2 to -15 bars resulted in a linear decrease. Reduction of shoot weight almost upto

50 per cent of that recorded at field capacity was resulted at -8 bars SWP. While relative dry weight of shoot declined linearly when SWP decreased from field capacity to -15 bars SWP. These results suggested that the growth rate of soybean had a direct bearing on transpiration rate, SWP and atmospheric conditions. Healthely (1980) and Osman Bin Ysuf et al. (1980) have also been reported that shoot dry weight of soybean plants were maximum at relatively high soil water level throughout the reproductive growth period.

5.2.3 The relationship between SWP and root growth was assessed by computing relative fresh and dry weight of soybean roots and the same have been depicted in Fig. 8. A linear decrease in relative fresh weight of soybean roots with decreasing SWP from -0.33 to -15 bars indicated that soybean root growth had direct bearing on SWP. The dry weight of soybean roots decreased sharply when SWP was decreased from -0.33 to -4 bars followed by a gradual decrease in -4 to -10 bars SWP and further decrease in SWP beyond -10 to -15 bars resulted in only marginal decrease (Fig.11). The results indicated that maximum dry matter accumulation in soybean root took place at field capacity moisture content and at sharply decreasing rates upto -4 bars SWP. A SWP range of -4 to -10 bars witnessed

dry matter accumulation only at very slow rate and ultimately no dry matter accumulation beyond -10 bars SWP. Singh (1983) and Sharma (1984) also reported similar results for safflower and barley plants respectively.

5.2.4 The relationship between SWP and shoot/root ratio of soybean has been shown in Fig. 9. It is indicated that the shoot/root ratio increased gradually from about 2 to 3 as SWP decreased from -0.33 to -4 bars. This emphasised that under restricted water availability root growth of soybean experienced relatively more adverse effect than shoot growth. SWP range of -4 to -10 bars did not cause any changes in shoot/root ratio as it remained about 3 throughout this range of SWP which indicated that shoot and root growth were equally affected in this range. Further decrease in SWP from -10 to -15 bars caused a considerable increase in shoot/root ratio from about 3.5 to 5.5 again indicating that in this range of SWP root growth of soybean experienced severe adverse effects than shoot growth in this SWP range also. Newman (1974), Christie (1975), Singh (1983) also reported the increase in shoot/root ratio of flax, grass and safflower respectively, with decreasing soil water potential. However, some workers have reported a decrease in shoot/root ratio with decreasing SWP in case of wheat and barley (Taylor) and Ratliff, 1969, Sharma 1984).

5.2.5 Fig. 10 shows the transpiration and relative transpiration rate of soybean under different treatments during its vegetative growth period. The differences in transpiration rate under different treatments may be attributed to the differences in initial soil water content. There was a sharp decrease in transpiration rate of soybean with decrease in SWP from -0.33 to -4 bars. Further decrease in SWP from -4 to -10 bars caused a gradual decrease in transpiration rate only upto 28th day of sowing. Beyond -10 bars SWP the transpiration rates were almost stabilized leading to a minimum value of  $0.06 \text{ g/cm}^2/\text{day}$  at -15 bars SWP despite of relatively higher atmospheric evaporativity in the later days suggests that the transpiration rate was independent of atmospheric conditions. The sharp decrease in transpiration rate initially in wet soil moisture range is attributed to reduced water availability because of sharp decline in hydraulic conductivity of a black clay soil with decreasing SWP. Later on a gradual decrease in transpiration rate might be due to integrated effect of hydraulic properties of soil as well as stomatal behaviour of soybean leaves. Below -4 bars SWP decrease in turgor pressure of leaves and thus closure of stomatal aperture might have caused gradual reduction in transpiration rate. Sionit et al. (1973) observed a rapid increase in transpiration

rate immediately after irrigation in both herbaceous and woody plants. As soil water was depleted rate of transpiration declined. Blanchet et al. (1977), Blanchet and Gelfi (1978) and Eavis and Taylor (1979) also reported that transpiration rate of soybean plants decreased with decreasing of soil water content.

### 5.3. NITROGEN FERTILIZATION :

5.3.1 The results on yield of soybean and its attributory characters as influenced by different treatments have been presented in tables 6 and 7. It is revealed from the data that the application of nitrogen in general caused a significant increase in plant height, number of pods/plant, fresh and dry weight of plants, grain number and weight of 10 plants as compared to control. The results clearly indicated that the soybean plant growth responded remarkably well to the application of 20 kg N/ha applied half through urea and half through F.Y.M. followed by 10 kg N/ha applied through F.Y.M. The possible reason for this might be that the combination of F.Y.M. with nitrogenous fertilizer, which are beneficial for plant growth as F.Y.M., releases the nitrogen and other nutrients gradually throughout the season and maintain good physical conditions of the soil. Tiwari (1975) reported

that no basal nitrogen is needed for soybean growth if F.Y.M. @ 25 cartload/hectare is mixed with the soil at the time of last bakharing. Decreasing levels of nitrogen applied through fertilizer caused a progressive decrease in all the growth characters in general. This decrease in the growth characters of soybean might be due to the fact that nitrogen is an essential constituent for plant growth which due to short supply caused decreased plant growth of soybean.

The data on grain and straw yield of soybean as given in table-7 and Fig.11 revealed that highest grain yield (20.23 q/ha) was obtained due to application of 20 kg N/ha half through urea and half through F.Y.M., which was statistically significant over all the other treatments under consideration. The possible reason for this might be that the application of nitrogen in combination of F.Y.M. increased phosphorus uptake markedly (Shinde and Datta, 1964) which is essential for seed formation. Anonymous (1983) also reported that maximum grain yield was recorded from nitrogen application through F.Y.M. The results indicated that application of Zinc with 20 kg N/ha through urea has given an additional advantage. It is also apparent from the results that decreasing N levels caused a marked reduction in soybean grain yield

(Anonymous, 1983). The thousand grain weight and soybean straw yield also followed a similar trend as grain yield. The results are in confirmity with the findings reported by Bangoo and Albrtton (1972), Agrawal and Narang (1975), Sable and Khuspe (1977), Barni et al. (1978), Kastori et al. (1979), Huang (1980) and Joshi (1980).

5.3.2 The results on the nutrient content in soybean grain and straw as influenced by different nitrogen levels, source and their combination, have been given in table 8 and 9. An appraisal of the tables revealed that the differences in nitrogen content of soybean grain due to treatments N<sub>20</sub> + Zn, N<sub>20</sub>( $\frac{1}{2}$  +  $\frac{1}{2}$  F.Y.M.) N<sub>10</sub> FYM and N<sub>20</sub> were statistically nonsignificant. It is apparent that decreased levels of nitrogen application through urea down to 20 kg/ha caused progressive decrease in N concentration in soybean grain. The nitrogen content in soybean straw due to different levels and source of nitrogen was significantly more as compared to controls. The treatments N<sub>20</sub> + Zn and N<sub>20</sub> ( $\frac{1}{2}$  +  $\frac{1}{2}$  F.Y.M.) were statistically at par in this respect while N content in treatments N<sub>20</sub>, N<sub>10</sub>, N<sub>10</sub>FYM and N<sub>16.7</sub> was observed to be significantly less. The differences in the concentration of phosphorus, potassium and calcium in grain were statistically nonsignificant, except magnesium content which

differed significantly. The differences in the concentration of phosphorus, calcium and magnesium in straw were statistically significant except potassium content which differed nonsignificantly.

Thus it can be concluded that the percentage content of nitrogen showed the increasing trend with increasing levels of nitrogen application through urea. The increased plant growth possibly resulted in dilution of nitrogen and other elements in the plant. The application of nitrogen increases the available nitrogen content of soil. The increased availability of nitrogen in soil increases nutrient absorption by the plants, Similar views have been put forth by Murneek (1937), Lethwell and Evanse (1951), Harway and Weber (1971), Bangoo and Albrtton (1972), Setty (1974), Pal and Saxena (1976), Hatam (1977), Rayer and Hat (1977) and Huang (1980).

5.3.3 The uptake of nutrients is a function of yield which in turn depends on a good balance of the major plant nutrients present in soil. Provided there is a good balance of the major nutrients, then they have a complimentary effect on the yield and ultimately on the uptake of the nutrients and in vigour and health of the plants, which brings in them the power to resist the attack of biotic

pest and ecological adversities. It is seen from the results given in tables 10, 11 and 12 that uptake of nitrogen, phosphorus, potassium, calcium and magnesium by grain and straw was significantly affected by different levels of nitrogen and source. The N uptake (118.27 kg/ha) by soybean grain due to N<sub>20</sub> ( $\frac{1}{2}$  +  $\frac{1}{2}$  FYM) was significantly more than due to any of the treatments under consideration. Decreasing levels of N applied through urea down to 20 kg N/ha caused a progressive decrease in N uptake by grain to a significant level. Application of different levels of nitrogen through urea and FYM caused the significant differences in uptake of P, K, Ca and Mg nutrients by soybean grain. Decreased levels of N in the range of 20 to 6.7 kg/ha showed a decreasing trend in the uptake of these nutrients by soybean grain. The trend in uptake of all these nutrients by soybean straw was decreasing with decreasing rate of N application. The differences in uptake were observed to be statistically significant. The total uptake obeyed similar trend as that shown by grain and straw independently. Thus, it may be concluded that the 20 kg N/ha half through urea and half through FYM increased the total uptake from the soil. The possible reason for that might be the increased availability of N and extracting power of plant roots increased in soil due to the FYM application along with urea.

Rayer and Hat (1977) concluded that inhibition in the uptake of potassium, calcium and magnesium by high levels of  $\text{NH}_4$  may be an important factor in the nutrients of soybean plants. Similar results on uptake of nitrogen and other nutrients by soybean plants at different growth period were also observed by Lethwell and Evanse (1951), Ohlrogge (1964), Hanway and Weber (1971), Harber (1971) and Courpront and Taizin (1975).

5.3.4 A glance at the data shown in table-13 revealed that application of nitrogen significantly increased the protein content and thus the estimated protein yield. The maximum protein content of 36.71% was recorded in treatment  $\text{N}_{20} + \text{Zn}$  which was significantly higher than all the other treatments under consideration. The maximum estimated protein yield of 7.39 q/ha was recorded due to  $\text{N}_{20}(\frac{1}{2} + \frac{1}{2} \text{ FYM})$  which was significantly more than rest of the treatments followed by  $\text{N}_{20} + \text{Zn}$  which gave 6.98 q/ha protein yield. The decreasing levels of nitrogen caused a progressive decrease in protein content and estimated protein yield. The results also indicated that FYM proved to be better than the urea as far as the protein yield was concerned.

The increase in the protein content and estimated protein yield of soybean grain due to the increasing

levels of nitrogen might be attributed to the fact that the nitrogen is an essential constituent of amino acid, which is structural unit of protein. Nitrogen is the key element in the synthesis of protein and result obtained expressed this fact. Increase in protein content due to application of nitrogen has also been observed by Fellers (1918), Wagner (1962), Singh and Singh (1968), Kesavan and Morachan (1974), Norman (1974), Agrawal and Narang (1975).

Table-13 also revealed that the oil content of soybean grain decreased significantly due to application of nitrogen. As far as the estimated oil yield was concerned it was significantly increased due to application of nitrogen and the trend was observed to be different from oil content data because of interacting effect of soybean grain yield. The estimated oil yield ranged in between 2.24 to 3.97 q/ha respectively under N<sub>0</sub> (Farmer's control) and N<sub>0</sub> ( $\frac{1}{2}$  +  $\frac{1}{2}$  FIM) treatments. The decrease in oil content in soybean grain might be attributed to the fact that nitrogen had no effect on oil content (Kesavan and Morachan, 1974). Similar observations were reported by Robert et al. (1954), Sood et al. (1977) and Paliwal (1981).

5.3.5 The results on correlation coefficients between different constituent of soybean grain are given

in table-14. It is seen from the table-14 that a positive and highly significant correlation was found between nitrogen and protein ( $r = 0.999^{++}$ ) in grain as expected whereas a negative and significant correlation were found in between nitrogen and oil ( $-0.769^+$ ) and protein and oil ( $-0.776^+$ ) in soybean grain. Similar results were also reported by O'Kelly and Geiger (1937), Cartter and Hopper (1942), Krober and Cartter (1962), Hartwing and Collins (1962), Johnson and Bernard (1963), Smirnova-Ikonnikova et al. (1971), Shannon (1972) and Lal et al. (1973).

Further, the correlation between phosphorus and protein, potassium and protein, calcium and protein, magnesium and protein, phosphorus and oil and potassium and oil were observed positively nonsignificant. The correlation between calcium and oil and magnesium were found negatively nonsignificant. As regards the positive correlation between oil and phosphorus and negative correlation between oil and nitrogen, similar observations were reported by Smirnova-Ikonnikova et al. (1977).

5.3.6 A balance sheet of available nitrogen in soil has been prepared for 0-15 cm and 15-30 cm layers and data have been presented in tables-15 and 16. A perusal of data presented in table-15 clearly

indicated that there was a net gain of nitrogen in 0-15 cm soil layer ranging from 1.90 to 23.20 kg/ha in treatment N<sub>0</sub> (Farmer's control) and N<sub>20</sub> + Zn respectively. The increase in the nitrogen content in 0-15 cm soil layer might be because of intensive nodule formation that might have remained unutilized. Balance sheet of available nitrogen content in the soil at 15 to 30 cm soil layers has been presented in table-16. The data indicated a net depletion of nitrogen in treatment N<sub>0</sub>(Control) and N<sub>0</sub>(Farmer's control) where no fertilizer was applied from any of the source. Other treatments caused a net gain available nitrogen in 15-30 cm soil layer. Increased rates of nitrogen application caused net gain of nitrogen at progressively increasing rates which may be because of proportionate intensive root growth in the subsurface layer resulting in to heavy fixation of atmospheric nitrogen. Importance of the legumes in rotation as the cheapest and more economic means of increasing soil nitrogen has been reported earlier (Thorn, 1919). Lyon and Bizzel (1934) reported that soybean is the most effective amongst the legumes as large gain of nitrogen in soil was associated with large nitrogen content of crops. Similar results were reported later on by Singh et al. (1938) and Smith et al. (1959).

## SUMMARY AND CONCLUSION

## SUMMARY AND CONCLUSION

Pot house studies were conducted to evaluate the influence of different levels of soil water potential on seedling emergence, plumule and radicle growth, transpiration rate and growth of soybean (JS 72-44) during vegetative growth period. A field experiment was also conducted to study the effect of different levels of nitrogen applied through urea and farmyard manure on yield, chemical and biochemical composition of soybean (JS 72-44) plants. The results obtained led to the following conclusions :

- (1) The maximum seedling emergence, plumule and radicle growth of soybean took place at field capacity moisture content (-0.33 bars SWP).
- (2) Decreasing SWP from -0.33 to -15 bars caused a progressive decrease and delay in seedling emergence, radicle and plumule growth of soybean. The decrease in seedling growth parameters in -0.33 to -5 bars SWP range were in tolerable limit indicating that for realising satisfactory emergence and growth of soybean seedling, soil moisture stress beyond 5 bars should be avoided
- (3) Maximum soybean plant growth viz. plant height, green leaf area enlargement, fresh and dry weight of shoot and root took place at field capacity

moisture content (-0.33 bars SWP) and decreased progressively almost in a linear manner with decreasing SWP from -0.33 to -15 bars.

- (4) The shoot/root ratio of soybean on dry weight basis increased gradually with decreasing SWP from -0.33 to -4 bars and -10 to -15 bars which emphasized that under restricted water availability root growth of soybean experienced relatively more adverse effect than shoot growth. An almost constant shoot/root ratio in -4 to -10 bars SWP indicated that shoot and root growth of soybean in this SWP range were equally affected.
- (5) There was a sharp decrease in transpiration rate of soybean with decrease in SWP from -0.33 to -4 bars. Further decrease in SWP from -4 to -10 bars caused a gradual decrease in transpiration rate only upto 28th day of sowing. Beyond -10 bars SWP, the transpiration rates were almost stabilized leading to a minimum value of  $0.06 \text{ g/cm}^2/\text{day}$ . In general the transpiration rate of soybean decreased with the age of the plants.
- (6) Application of nitrogen in general caused a significant increase in growth, yield and attributory characters of soybean plants as compared to control.

- (7) The results indicated that the highest grain yield (20.23 q/ha) was obtained due to application of 20 kg N/ha half through urea and half through FYM which was statistically significant over all the other treatments under consideration. Next in order were the N<sub>20</sub> + Zn (19.03 q/ha grain yield) and N<sub>20</sub>(18.82 q/ha grain yield) treatments respectively as far as their effect on grain yields were concerned.
- (8) The result indicated that application of ZnSO<sub>4</sub> @ 25 kg/ha gave an additional advantage as far as the grain yield, nitrogen and protein content were concerned.
- (9) The nitrogen content in soybean plant increased significantly with increasing levels of soil applied nitrogen.
- (10) The uptake of nitrogen, phosphorus, potassium, calcium and magnesium by soybean grain and straw was significantly affected by different levels of nitrogen and source. The trend in total uptake of different nutrients matched with the trend of grain and straw yield obtained under different treatments.
- (11) Application of nitrogen significantly increased the protein content and estimated protein yield.

The maximum protein content (36.71%) was recorded in treatment N<sub>20</sub> + Zn which was significantly more than obtained due to N<sub>20</sub> (36.52%). Decreasing levels of nitrogen caused progressive decrease in protein content.

- (12) Oil content of soybean grain decreased significantly due to application of nitrogen. It varied from 20.31% under farmer's control i.e. N<sub>0</sub> to 19.60% in N<sub>20</sub> + Zn. The differences in oil content under treatments N<sub>20</sub>, N<sub>10</sub>, N<sub>10</sub>FYM and N<sub>16.7</sub> were only marginal and statistically nonsignificant.
- (13) There existed a significant positive correlation ( $r = 0.999^{++}$ ) between protein and nitrogen content of soybean grain while oil and nitrogen content of soybean were significantly negatively correlated ( $r = -0.769^+$ ). Similarly protein and oil content of soybean were significantly negatively correlated ( $r = -0.776^+$ ).
- (14) Balance sheet of available nitrogen in soil indicated a net gain of nitrogen in 0-15 cm soil layer ranging from 1.90 to 23.20 kg/ha nitrogen. Similarly in 15-30 cm soil layer, gain of nitrogen ranged from 3.07 to 23.5 kg/ha in various treatments except in controls from where there was a net depletion of about 1.5 kg N/ha.

- (15) Increasing rates of soil applied nitrogen caused a net addition of nitrogen at increasing rates in soil.

## BIBLIOGRAPHY

## BIBLIOGRAPHY

- Agrawal, S.K. and Narang, R.S. (1975). "Effect of levels of phosphorus and nitrogen of soybean varieties". Haryana Agric. Univ. J. Res. 5(4), 303-308.
- Albert, W.A. (1933). "Inoculation of legumes as related to soil acidity". J. Amer. Soc. Agron. 25, 512-522.
- Anonymous (1983). "Annual Progress Report of the All India Coordinated Project on Dryland Agriculture Research". J.N.K.V.V. Campus, Indore.
- Ayers, A.D. and Hayward, H.E. (1948). "A method for measuring of soil salinity on seed germination with observation on several crop plant." Soil Sci. Soc. Amer. Proc. 13, 224-226.
- Bangoo, M.S. and Albrtton, D.J. (1972). "Effect of fertilizer nitrogen, phosphorus and potassium on yield and nutrient content of Lee soybean." Agron. J. 64, 743-746.
- Barni, N.A.; Gomes, J.B.; Das, Concolves, J.C. (1978). "Responses of soybean to application of nitrogen fertilizer at flowering." Agron. Sulriog. 14(2), 243-250.
- Berlato, M.A. and Bergamaschi, H. (1979). "Water use by soybean. 1, Seasonal evapotranspiration in conditions of optimal soil water availability." Cent. Naci. de Pes. de Soja, 53-58.

- Bhargava, O.P.; Verma, G.P.; Russel, M.B. and Katre, R.K. (1976). "Soil moisture depletion under maize and soybean crops grown on deep black soil." J. Indian Soc. Soil Sci. 24(2), 158-162.
- Black, C.A. (1965). Methods of soil Analysis (Part-2). Am. Soc. Agron. Madison Wisconsin.
- Blanchet, R.; Gelfi, N. and Bose, M. (1977). "Relationship between water use and yield of various varietal types of soybean." Annales, Agron. 28(3) : 261-275.
- Blanchet, R. and Gelfi, N. (1978). "Relationship between leaf development, transpiration and production in soybean." Annales, Agron. 29 (3) , 223-242.
- Blizzard, W.E. and Boyer, J.S. (1980). "Comparative resistance of the soil and the plant to water transport." Plant Physio. 66(5), 809-814.
- Boot, K.J. and Bennett, J.M. (1980). "Teaching techniques in crop water relations, gas exchange and growth analysis." Amer. Soc. of Agron. 9.
- Boyer, J.S. (1970). "Leaf enlargement and metabolic rates in corn soybean and sunflower at various leaf water potential." Plant Physio. 43, 233-235.

- Bunce, J.A. (1978). "Effect of shoot environment on apparent root resistance to water flow in whole soybean and cotton plant." J. Exp. Bot. 29 (110), 595-601.
- Bunce, J.A. (1978). "Effect of water stress on leaf expansion, net photosynthesis and vegetative growth of soybean and cotton." Canadian J. Bot. 56 (13), 1492-98.
- Carlson, R.E.; Momen, N.N.; Arjmand, O. and Shaw, R.H. (1978). "Leaf water potential and diffusive resistance relationships to yield components of soybeans." State J. Res. 53 (2), 161-175.
- Carter, J.L. and Hopper, T.H. (1942). "Influence of variety environment and fertility level on the chemical composition of soybean." U. S. D. A. Tech. Bull. 787.
- Cavaleri, A.J. and Boyer, J.S. (1982). "Water potentials induced by growth in soybean hypocotyles." Plant Physiol. 69(2), 492-496.
- Chapman, H.D. and Pratt, P.F. (1961). Methods of analysis for soil plant and water. University of California, U. S. A.

- Chaudhary, T.N. and Ghildyal, B.P. (1970). Quoted by Chopra Usha K. and Chaudhary, T.N. (1981). Seedling of wheat and gram in relation to soil water potential, temperature and seedling depth. J. Indian Soc. Soil Sci. 29(4):437-440.
- Collis-George, N. and Hester, J.B. (1966). "Germination of seed as influenced by water potential and area of contact between seed soil water." Aust. J. Res. 4, 145-164.
- Collis-George, N. and Sands, J.E. (1959). "The control of seed germination by moisture as a soil physical property." Aust. J. Agric. Res. 10, 628-635.
- Collis-George, N. and Sands, J.E. (1962). "Comparison of the effect of physical and chemical components of soil water energy on seed germination." Aust. J. Agric. 13, 575-584.
- Coupront, C. and Tauzin, J. (1975). "Nutrient uptake by a soybean crop on irrigated sandy soil in Gascony." Academie d' Agril. de France 61(15), 963-980.
- Detmer, W. (1898). "Practical Plant Physiology. Swan. Sonnenschein and Co. London. Mac. Millian & Co. New York.

- Eavis, B.W. (1972). "Soil physical conditions affecting seedling root growth. I. Mechanical impedance, aeration and moisture availability as influenced by bulk density and moisture levels in sandy loam soil." Plant Soil 36, 613-622.
- Eavis, B.W. and Taylor, H.M. (1979). "Transpiration of soybean as related to leaf area, root length and soil water content." Agron.J. 71(3): 441-445.
- Faiz, S.M.A. and Hague, I. (1977/1978). "Studies of leaf relative water content of field grown soybean under different soil moisture regimes and evaporative conditions." Bangladesh J. Bio. Sci. 6/2 (1), 1-4.
- Fellers, C.R. (1918). "The effect of inoculation, fertilizer treatments and certain minerals on the yield composition and nodules formation of soybean." Soil Sci. 6. 81-119.
- Fisher, R.A. (1950). Statistical method for research workers. Aliver and Boyd Ltd., London.
- Fisher, R.A. and Hagan, R.M. (1965). "Factors affecting the penetrating ability of roots." Diss. Abstr. 23 1949.
- Fuleky, G. (1947). "The protein and oil content of soybean artificially fertilized." Biol. Abs. 21.

- Gardener, H.R. and Danielson, R.E. (1964). "Penetration of wax layers by cotton roots as affected by some soil physical conditions." Soil Sci. Soc. Amer. Proc. 28, 457-460.
- Gingrich, J.R. and Russell, M.B. (1956). "Effect of soil moisture tension and O<sub>2</sub> concentration on the growth of corn root." Agro.J. 48, 517-520.
- Gupta, Ram K. and Khajan Singh (1975). "Influence of soil moisture potential on radicle elongation of wheat and mung grown in clayey soil." Mysore J. Agric. Sci. 2, 627-634.
- Hadas, A. (1970). "Factors affecting seed germination under moisture stress." Israel J. Agric. Res. 20, 3-13.
- Hanway, J.J. and Weber, C.R. (1971). "Accumulation of N, P and K by soybean (*Glycine max* (L.) Merrill) Plants." Agron. J. 70 (5), 779-783.
- Harper, J.E. (1971). "Seasonal nutrient uptake and accumulation patterns in soybeans." Crop Sci. 11, 347-350.
- Hartwig, E.D. and Collins, F.I. (1962). "Evaluation of density, classification as a selection technique in breeding soybean for protein and oil." Crop Sci. 2, 162-195.

- Hatan, M. (1977). "Effect of various sources of nitrogen and added organic matter on nodulation, nodules activity and nitrogen content in soybean." J. Sci. and Technology. 1 (1), 31-35.
- Hatfield, J.L. and Carlson, R.E. (1979). "Leaf-water potential pattern within two soybean cultivars." J. Res. 53 (4), 259-267.
- Heatherly, L.G. (1980). "Growth of soybeans at different soil matric potentials." Soil Sci. 130(6), 331-335.
- Heatherly, L.G. and Russell, W.J. (1979). "Effect of soil water potential of two soils on soybean emergence." Agron. J. 71 (6), 980-982.
- Hiler, E.A. (1972). "Sensitivity of southern peas to plant water deficits at three stages." Agron. J. 64, 60-64.
- Hipps, L.E. and Hatfield, J.L. (1980). "The influence of morphological adaptation to water stress on crop microclimate." Amer. Soc. Agron. 12.
- Horner, G.M. (1936). "Relation of degree of base saturation of colloidal clay by calcium to the growth, nodulation and composition of soybean." Mo. Agri. Exp. Sta. Res. Bull. 232.

- Huang, H.Y. (1980). "Study on nutritional and physiology of soybean. 1 Response of autumn cropped soybean to nitrogen." Res. Bull. Tainan. Dist. Agri. Impr. Sta. 14. 71-78.
- Huck, M.G.; Busch, C.D. and Peterson, C.M. (1981). "Soybean adaptation of water stress." Amer. Soc. Agron. 87.
- Hunter, J.R. and Erickson, A.E. (1952). "Relation of seed-germination to soil moisture tension." Agron. J. 63, 107-109.
- Hunter, M.N.; Jabrun, P.L.M. De and Byth, D.E. (1980). "Response of nine soybean lines to soil moisture conditions close to saturation." Aust. J. Exp. Agri. and Animal Husb. 20 (104), 339-345.
- Iden, T. (1961). "Effect of soil moisture tension on root growth." Bull. Far. Agric. Macunir 24; 37-44.
- Jackson, M.L. (1958). Soil chemical analysis. Prantice Hall. Inc. England. Cliffs, N.J.
- Jensen, R.D. (1971). "Effect of soil water tension on the emergence and growth of cotton seedling." Agron. J. 44, 766-768.
- Johnson, H.W. and Bernard, R.L. (1963). "Soybean genetics and Breeding. In the soybean A.G. Norman (Editor) Academic Press, New York."

- Jones, J.W.; Zur, B.; Boote, K.G. and Hammond, L.C. (1980).  
"Validation of a soil plant-water model."  
Amer. Soc. Agron. 13.
- Joshi, R. (1980). "Response of black soybean to phosphorus application in vertisols of Indore (Malwa)."  
Thesis submitted to J.N.K.V.V. for M.Sc. (Ag.) degree.
- Karlen, D.L.; Hunt, P.G. and Matheny, T.A. (1980).  
"Nutrient uptake and yield of determinate soybeans grown under varying soil-water regimes."  
Amer. Soc. Agron. 170.
- Kastori, R.; Belic, B.; Petrovic, N.; Molnar, I. and Dzilitor, S. (1979). "Changes in content, accumulation and distribution of N, P, K, Ca and Mg during vegetative growth in some cultivars of soybean." Savremena Poljoprivreda 27 (9/10) 433.
- Kesavan, G. and Morachn, Y.B. (1974). "Response of soybean to graded doses of nitrogen and phosphorus."  
Oilseed J. IV. No. 3, 1-6.
- Khan, A.R. and Varade, S.B. (1976). "Water diffusivity of gram arhar and pea seeds during germination."  
The Harvester.
- Karamer, P.J. (1959). "Transpiration and water economy of plants, in "Plant Physiology A Treatise." F.C. Steward ed. Vol. II pp 667. Academic Press, New York.

Krishnamurty, K.K.; Jagannath, M.K.; Rajaschekera, B.G. and Raghunatha, G.C. (1974). Estimation of leaf area in grain sorghum from single leaf enlargement. Agron. J. 66, 344-345.

Knowles, F. and Watkins (1950). A practical course in Agricultural chemistry. Macmillan and Co. Ltd., London.

Krober, O.A. and Cartter, J.L. (1962). "Quantitative relationship of protein and non protein constituents of soybean." Crop Sci. 2, 171-172.

Lal, M.S.; Mehta, S.K.; Deodhar, A.D. and Sharma, Y.K. (1973). "Protein and oil content, their correlation and phenotypic stability in soybean as influenced by different environments in M.P." Indian J. Agric. Sci. 43 (1), 14-17.

Lethwell and Evanse, E.E. (1951). "Nitrogen uptake from solution by soybeans at successive stage of growth." Agron. J. 43, 269-270.

Longstreth, D.J. and Kramer, P.J. (1980). "Water relations during flower induction and anthesis." Bot. Gazette 141 (1), 69-72.

Lozano, M.H.L. and Villages, J.A. and Rogriguez, M.E.L. (1978). "Influence of soil moisture on seed set setting in soybeans." Mis Facu. de agron Zoo. Univ. Nac. de Jucu. 66 15 pp.

- Lyon and Bizzel (1934). Effects of legumes on crop rotation. Cornell Agric. Exp. St. Bull. 294.
- McCally, R.M. (1937). "Behaviour of legume bacteria (Rhizobium) in relation to exchangeable calcium and hydrogen ion concentration of the colloidal fraction of the soil." Mo. Agr. Exp. Sta. Res. Bull. 256.
- Mensah, J.K., Blaisdell, G.L. and Geankoplis, C.J. (1979). "Hydroscopic properties and moisture diffusivities of soybean seed coat and cotyledons." ASAE paper No. 79-3058, 19 pp
- Meyer, G.E. (1979). "Simulation of moisture stress effects on soybean yield components in Nebraska. ASAE Paper No. 79-4522, 27 pp
- Meyer, W.S. and Walker, S. (1981). "Leaflet orientation in water stressed soybean." Agron. J. 73 (6), 1071-1074.
- Momen, N.N.; Carlson, R.E.; Shaw, R.H. and Arjmand, O. (1979). "Moisture stress effects on the yield components of two soybean cultivars." Agro. J. 71 (1), 86-90.
- Murneek, A.E. (1937). "Biochemical studies of photoperiodism in plants." Missouri. Agri. Exp. Sta. Res. Bull. 268.
- Naik, L.B.; Panchal, Y.C.; Kulkarni, G.M. (1978). "Effect of moisture stress on soybean seedling raised from the hardend seeds." Current Res. 7 (22), 283-294.

- Newman, E.I. (1974). "In E.W. Carson (ed.). The plant roots and its environment." 363-440, Virginia Univ. Press Cherlottesiville.
- Nomota, Ta. (1967). "Theory and practice of rice culture (in) Theory and practice of growing rice." pp 336-48 Matsubayashi M. ITO 170. R. and Takase T. FUJI (Eds) Tokyo.
- Norman, A.G. (1974). "The nitrogen nutrition of soybean. Proc. Soil Sci. Soc. Amer. 8., 226-228.
- Ohlrogge, A.J. (1964). "Miniral nutrition of soybeans." p. 126-158 in A.G. Norman (ed.). The soybean Acade. Press New York.
- O'Kelly, J.E. and Geiger, M. (1937). "Effect of variety maturity and soundness of certain soybean seed and oil characteristics". Mississippi Agr. Exp. Sta. Bull. 24.
- Olsen, S.R.; Cole, C.V.; Watanbe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soil by extraction with sodium bio-carbonate. U.S.D.A. Circ. 939.
- Osman Bin Yysof; Patterson, R.P. and Raper, C.D. Jr. (1980). "Growth and yield of soybean as affected by water deficits." Amer. Soc. Agro. 25.

- Pal, U.R. and Saxena, M.C. (1976). "Relationship between nitrogen analysis of soybean tissues and soybean yield." Agron. J. (6), 927-932.
- Paliwal, B. (1981). "Varietal difference in uptake of nutrients (N.P.K.) and certain Biochemical composition in soybean." Thesis submitted to J.N.K.V.V. for M.Sc. (Ag.) degree.
- Panse, V.G. and Sukhatme, P.V. (1967). Statistical Methods for Agricultural Workers. I.C.A.R., New Delhi, p.67-69.
- Phillips, R.C. (1968). "Water diffusivity of germinating soybean, corn and cotton seed." Agron. J. 60, 568-571.
- Piper, C.S. (1950). Soil and plant analysis. Inter science Publishers. Inc. New York.
- Planchon, C. and Vignes, D. (1978). "Study of the transpiration and stomatal regulation of two cultivars of soybean, results of the creation of low water requirement types." Ann. del'Amel. des. Plantes 28(2), 149-155.
- Rajput, R.P. and Gupta Ram K. (1978). "Effect of soil water potential on transpiration rate and leaf water potential of wheat, niger and lentil." J. Agron. and Crop Science 147, 60-67.
- Ramagnoli, M. (1949). "Investigation on soybean growing in Italy." Biol. Abstr. 25, 1951.

- Rao, A.B.J. and Gupta Ram K. (1976). "Influence of soil moisture suction and depth of sowing on seedling emergence of soybean in clayey soil." Seed Research 4 (1), 124-129.
- Ravankar, H.N. and Badke (1975). "Effect of phosphorus on yield uptake of nitrogen, phosphorus and quality of urid, moong soybean." Punjabrao Krishi Vidyapeeth Res. J. 3 (2), 145-146.
- Rayer, A.J. and Hat, T.V. (1977). "Effect of  $NH_4$  on uptake of P, K, Ca and Mg by intact soybean plants." Plant and soil 48 (1), 81-87.
- Reicosky, D.C.; Karper, T.C. and Taylor, H.M. (1980). "Changes in resistance to water transport in field grown soybean." Amer. Soc. Agron. 14-15.
- Richard, L.A. (1949). Methods of measuring soil moisture tension. soil sci. 68: 95-112.
- Richards, L.A. and Wadleigh, C.H. (1952). "Soil water and plant growth. In B.T. Shaw(ed.) Soil Physical conditions and plant growth." Academic Press Inc. New York, 73-251.
- Richards, L.A. (1954). Diagnosis and improvement of saline and alkali soils. U.P.D.A. Hand Book 60
- Richards, L.A. and Weeks (1957). "Moisture movement in soils." Calf. Agric. Vol. II (a), 24-27.

- Robert, D.; Oster and Cartter, J.L. (1954). "Effect of planting data on chemical composition and growth characteristics of soybean. Agron.J. 46, 267-270.
- Sable, R.M. and Khuspe, V.S. (1977). "Application of bacterial culture nitrogen and phosphatic fertilization to soybean." J. of Maharashtra Agric.
- Samet, J.S. and Cortes, P.M. (1980). "ABA and proline in soybean under water stress." Amer. Soc. Agron. 91.
- Setty, R.A. (1974). "The effect of fertilizer levels and time of application on growth, N uptake and yield of soybean." Field Crop Abstr. 27 (2), 4525.
- Shannon, J.G. (1972). "selection for protein and yield in six soybean population." Dessertation Abs. Internations B. 32 (9) 4983.
- Sharma, S.M.; Mehta, S.K. and Lal, M.S. (1977). "J.S.2, a high yielding soybean for M.P." Indian Farming 27 (5) 13, 15.
- Sharma, S.P.; Gupta, Ram K. and Kauraw, D.L. (1981). "Transpiration and leaf water potential of wheat in relation to changing soil water potential." J. Agron. and Crop Sci. 150, 264-270.
- Sharma, R. (1984). "studies on the effect of soil water potential on seedling emergence, transpiration, leaf water potential and growth parameters of barley (Hordeum Vulgare)". Thesis submitted to J.N.K.V.V. for M.Sc. (Ag.) degree.

- Shinde, J.E. and Datta, N.P. (1964). Bull National Inst. Sci. India. 26, 279.
- Singh, B.N.; Singh, S.N. and Gupta, P.P. (1938). "Fertility value of cultivated land as influenced by crop residue and season." Indian J. Soil Sci. 45, 631-684.
- Singh, V. and Singh, J.P. (1968). "Effect of spacing, nitrogen and phosphorus levels on yield and protein content of soybean. Madras. Agric. J. 55 (3), 129-133.
- Singh, B.R. (1963). "Studies on the effect of soil water potential on seedling emergence, transpiration, leaf water potential and growth parameters of safflower (*Carthamus tinctorius*)". Thesis submitted to J.N.K. V.V. for M.Sc. (Ag.) degree.
- Sionit, N. and Henderson, D.W. (1973). "Changes in stem diameter of herbaceous and woody plants as a measures of internal water-balance." Indian J. Agric. Res. 2, 39-56.
- Sivakumar, M.V.K. and Shaw, R.H. (1978). "Relative evaluation of water stress indicators for soybeans. Agro.J. 70(4), 619-623.
- Slatyer, R.O. (1967). "Plant water relationship." Academic Press Inc. New York.

Smirnova - Ikormikova; Korsokov, M.L.; Verelova, B.P. and Voskresenakay (1971). "Biochemical studies on soybean seeds." Trudy Po prikladnoi Botanike Genetike Selektaii 44 (3) , 275-284.

Smith, F.K.L.; Davidson, F.C. and Peterson, V.H. (1955). "Soil fertility investigation at Coloumbus Experimental fields." Kansas Agri. Exp. Sta. Bull. 372.

Smith, A.K. and Cirele, J.S. (1972). "Soybean chemistry and Technology, Protein Vol.1 Avi. Publishing West Port Conn. U.S.A.

Snyder, R.L.; Carlson, R.E. and Shaw, R.H. (1982). "Yield indeterminate soybeans in response to multiple periods of soil-water stress during reproduction." Agron. J. 74 (5), 855-859.

Sokolova, I. I. (1977). "Amino acid composition of proteins of soybean seed." Flora Dalnogo Vostoka, Blagoveshchensk, U.S.S.R. 38-54.

Sokolova, I. I. and Khvan, A. V. (1977). "Effect of excessive soil moisture on amino acid composition of proteins of soybean seed." Flora Dalnogo, Vostoka Blagoveshchensk. U.S.S.R. , 121-127.

- Sood, D.R.; Wagle, D.S.; Nanawatte, H.S. and Gupta, Y.B.  
(1977). "Varietal differences in chemical composition of soybean (*Glycine max* (L.) Merrill) J. Food Sci. and Tech. India 14 (4), 177-179.
- Stiles, J.E. (1948). Relations of water to the germination of corn and cotton seeds. Plant Physiol. 23, 201-202.
- Stiles J.E. (1949). Relations of water to the germination of bean seeds. Plant Physiol. 24, 540-545.
- Subbiah, B.V. and Asija, G.L. (1956). A rapid method for the estimation of nitrogen in soils. Curr. Sci. 25, 259-260.
- Sutherland, P.L. and Danielson, R.E. (1980). "Soybean response to water deficits during specific growth stages." Boulder, Colorado, Westview Press, 73.
- Tambi, A.B.; Patterson, R.P.; Gross, H.D. and Raper, C.D. Jr.  
(1980). "Relationship of soil moisture to growth and nitrogen assimilation by field grown soybean." Boulder, Colorado, Westview Press, 62.
- Taylor, H.M. and Rattiff, L.F. "Root elongation rates on cotton and peanuts as a function of soil strength and soil water content." Soil Sci. 108, 113-119.
- Tedia, K. (1984). "Effect of graded doses of single super phosphate on the yield and chemical composition of different genotypes of soybean." Thesis submitted to J.N.K.V.V. for M.Sc. (Ag.) degree.
- Thorn, C.F. (1919). "The maintenance of soil fertility." Ohio Agric. Exp. Sta. Bull. 336-581.

- Tiwari, U.C. (1975). "Fertilization on double cropping sequence of soybean and moong followed by safflower under dryland conditions." Thesis submitted to J.N.K.V.V. for M.Sc. (AG.) degree.
- Todmar, N. and Hillel, D. (1965). "Establishment and maintenance of seeded dryland range under semi arid condition." Res.Rep.National and Univ. Instt. of Agriculture. Valeani Instt. of Agril.Res.Rehovot, Isreal, p. 40, Illus.
- Vaadia, Y.; Franklin, G. Roney and Rober, M.H. (1961). "plant water deficit and physiological process." Ann. Rev. Plant Physiol. 12, 265-292.
- Vendeland, J.S.; Cortes, P.M. and Sinclair, T.R. (1980). "Response of field grown soybeans to drough stress II-Growth characteristics." Amer.Soc. Agron. 94.
- Vittam, M.T. and Mulvey, R.R. (1944). Better Crops 28(5) 6-10, 45-46.
- Wang, S.R. and Wang, G.M. (1980). "study of resistance to drough-water saturation difieit and stomatal diffusive resistance in soybean cultivars." Londrina, Brazil, Centro Naci, de.Pes.de Soja 299-301.
- Wagner, G.H. (1962). "Nitrogen fertilization of soybean." Missouri Agric. Exp. sta. 23. Field Crop abstr. 16 1963.

- Weatherley, P.E. (1950). "Studies in the water relation of the cotton plant. I. The field measurement of water deficit in leaves." New Phyto. 40, 81-97.
- Wenkert, W.; Remon, E.R. and Sinclair, T.R. (1978). "Leaf elongation and turgor pressure in field grown soybean." Agron. J. 70 (5), 761-764.
- Wien, H.C.; Littleton, E.J. and Ayanala, A. (1979). "Drought stress of cowpea and soybean under Tropical conditions." (From stress physiology in crop plants, a Wiley-Inter Science Publication) John Wiley and Sons, New York, Chicester Brisbane, Toronto.
- Wolfe and Kipps (1959). Thesis submitted by Mitra (1980), to the Department of soil Science, J.N.K.V.V. Jabalpur (M.P.)
- Woodstock, L.W. and Tao, K. (1980). "Prevention of imbibitional injury in low vigour soybean axes by osmotic control of water uptake." Amer. Soc. Agron. 113.
- Yadava, B.S. (1980). "Studies on the effect of inoculation, N and P fertilization and moisture regimes on the soybean production." Thesis Abstr. (2) 86-87 Haryana Agri. University.

Yaklich, R.W. and Cregan (1980). "Moisture migration in soybean pod." Amer.Soc. Agron. 113.

Zeljkovich, L.T.De (1981). "Contribution to the study of the characteristics of drought resistance in soybean." Field Crop Abstract 34 (4), 2709.

**APPENDICES**

APPENDIX - I

Meteorological observation during the period of Pot house study.

Date	Temperature <sup>°C</sup>		Humidity (%)	Open Pan evaporation (mm/day)
	Maximum	Minimum		
1	2	3	4	5

July, 1985

15	31	23	79.0	5.0
16	28	23	78.5	6.0
17	29	22	91.0	5.5
18	26	22	86.0	7.0
19	27	21	86.0	5.0
20	30	23	88.5	5.0
21	32	23	82.5	10.0
22	29	23	82.5	5.0
23	32	22	86.5	5.0
24	29	23	82.5	3.0
25	29	23	96.0	2.0
26	29	21	90.5	5.0
27	28	22	91.0	3.0
28	27	22	90.5	2.0
29	28	22	91.0	5.0
30	27	22	95.5	5.0
31	26	23	95.5	5.0

August, 1985

1	25	22	91.0	5.0
2	29	23	96.0	5.0
3	28	23	91.0	1.0

(contd.)

(Appendix - I contd.)

1	2	3	4	5
4	28	22	96.0	5.0
5	28	22	86.0	5.0
6	28	22	90.5	5.0
7	27	22	95.5	6.0
8	25	23	95.5	1.0
9	23	20	95.5	2.0
10	22	19	95.0	2.0
11	24	21	91.0	2.0
12	25	23	91.0	5.0
13	27	23	91.0	1.0
14	27	22	95.5	1.0
15	27	22	95.5	1.0
16	26	22	95.5	5.0
17	27	22	95.5	2.0
18	27	22	90.5	6.0
19	24	22	95.5	4.0
20	26	22	91.0	3.0
21	27	22	91.0	3.0
22	27	22	86.0	4.0
23	28	22	86.0	5.0
24	28	22	91.0	3.0
25	26	22	86.0	3.0
26	28	21	86.0	5.0

APPENDIX - II

Meteorological observation during the  
period of field experiment.

Date	Temperature <sup>°C</sup>		Humidity (%)	Open Pan evaporation (mm/day)
	Maximum	Minimum		
<u>June, 1984</u>				
30	35	25	78.0	8.0
<u>July, 1984</u>				
1	34	24	96.0	5.0
2	29	23	91.0	5.0
3	28	23	91.0	5.0
4	32	24	91.0	5.0
5	32	23	91.0	5.0
6	28	23	91.0	3.0
7	29	24	83.0	4.0
8	30	23	87.0	3.0
9	25	22	87.0	3.0
10	29	23	91.0	5.0
11	29	23	87.0	5.0
12	30	22	79.0	5.0
13	32	22	75.0	5.0
14	33	25	75.0	9.0
15	32	23	81.0	6.0
16	31	23	91.0	5.0
17	30	24	81.0	5.0
18	32	22	91.0	5.0
19	27	23	91.0	4.0
20	27	22	87.0	3.0

(contd.)

(Appendix-II Contd.)

1	:	2	:	3	:	4	:	5
21		28		23		75.0		3.0
22		29		23		74.0		4.0
23		29		22		90.0		3.0
24		28		22		82.0		4.0
25		30		23		95.0		3.0
26		27		23		78.0		7.0
27		29		23		69.0		3.0
28		29		22		87.0		2.0
29		28		22		86.0		5.0
30		29		22		86.0		5.0
31		31		23		79.0		6.0

August, 1984

1	33	24	78.0	6.0
2	29	21	96.0	3.0
3	24	22	96.0	2.5
4	21	21	96.0	2.0
5	22	21	96.0	3.0
6	22	20	90.0	4.0
7	26	22	81.0	5.0
8	25	22	81.0	5.0
9	27	21	91.0	2.0
10	23	21	95.0	2.0
11	23	21	95.0	3.0
12	23	19	91.0	3.0

(Contd.)

(Appendix-II contd.)

1	:	2	:	3	:	4	:	5
13		26		22		91.0		5.0
14		29		22		90.0		5.0
15		27		22		95.0		3.0
16		25		22		96.0		5.0
17		23		21		90.0		5.0
18		23		22		92.5		3.0
19		22		21		92.5		3.0
20		24		21		95.0		5.0
21		26		22		86.0		3.5
22		28		21		86.0		5.0
23		27		22		87.0		5.0
24		25		21		96.0		5.0
25		25		21		91.5		5.0
26		25		21		86.0		5.0
27		25		21		86.0		3.0
28		26		22		91.0		2.2
29		26		22		95.0		3.0
30		26		21		91.0		4.5
31		27		21		91.0		5.0

September, 1985.

1	26	21	90.0	5.0
2	25	21	90.0	5.0
3	25	21	90.0	5.0
4	25	21	90.0	4.0
5	23	21	86.0	3.0

(Contd.)

6	23	21	86.0	5.0
7	23	21	86.0	5.0
8	26	21	86.0	5.0
9	26	20	86.0	5.0
10	27	21	90.5	5.0
11	29	22	82.5	5.5
12	26	23	85.5	5.0
13	30	22	95.5	5.0
14	27	21	86.0	5.0
15	28	20	82.0	6.0
16	27	21	82.0	5.0
17	27	20	86.0	5.0
18	27	19	86.0	6.5
19	28	19.0	86.0	6.0
20	29	18	85.0	5.5
21	29	19	86.0	6.0
22	31	18	82.5	6.0
23	32	19	70.5	5.0
24	32	20	82.5	5.0
25	30	22	74.0	4.5
26	30	22	86.0	4.0
27	30	22	74.5	5.0
28	31	21	74.0	6.0
29	33	22	67.0	6.5
30	32	21	96.0	3.5

(Contd.)

1 : : 5  
2 : : 4  
3 : : 3  
4 : : 5

(Appendix-II contd.)

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1	:	2	:	3	:	4	:	5
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October, 1984

1	33	22	65.0	5.0
2	33	23	77.5	5.0
3	32	19	86.0	5.0
4	32	18	77.5	5.0
5	32	20	78.0	5.0
6	32	19	90.0	4.0
7	32	21	77.5	5.0
8	32	23	95.5	5.0
9	29	22	82.0	5.0
10	29	18	86.0	4.5
11	23	15	77.2	5.0

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APPENDIX - III

Moisture retention during absorption of deep black  
Clay soil (weight basis )

Suction (-bars)	Moisture content (Per cent)					Average
	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	
0	59.0	58.5	58.0	58.5	59.0	58.60
0.33	34.5	34.8	34.4	34.5	33.8	34.40
1	31.9	31.5	31.2	31.6	31.0	31.44
2	28.8	29.5	28.8	29.6	29.6	29.14
4	27.0	26.5	26.8	27.6	26.5	26.76
5	24.5	24.8	24.5	24.8	24.5	24.62
6	23.5	23.8	23.4	23.6	24.0	23.66
10	20.6	21.0	20.8	20.5	20.0	20.58
13	18.5	18.8	18.8	18.5	18.9	18.70
15	16.9	17.5	17.2	17.8	10.0	17.46

APPENDIX - IV

Average height of soybean plants (cm) at different times as affected by different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	17.80	26.65	34.44	39.50	43.65	47.75
1.20	30.00	15.19	25.00	30.00	35.20	40.40	45.39
4.00	26.76	12.46	17.32	23.76	26.07	28.37	31.99
10.00	20.58	7.01	9.99	11.74	12.10	13.21	13.50
15.00	17.46	4.25	8.40	10.12	10.60	10.65	10.65

APPENDIX - V

Average number of green leaves/2 plants at different times as affected by different treatments

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Day after start of experiment					
		7	14	21	28	35	42
0.33	34.40	16.50	26.60	30.56	32.80	34.95	35.80
1.20	30.00	15.25	23.21	26.36	28.16	30.10	30.85
4.00	26.76	13.22	20.80	22.51	24.32	26.13	26.68
10.00	20.58	8.50	12.36	13.94	14.58	15.03	15.09
15.00	17.46	3.18	6.48	7.49	8.05	8.08	8.08

APPENDIX - VI

Total green leaf area (cm<sup>2</sup>/2 plant) of soybean  
at different times under different treatment

Soil water potential (-bars)	Soil moisture content on weight basis(%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	179.64	309.70	448.86	562.91	678.53	800.10
1.20	30.00	118.32	204.85	314.00	399.66	500.66	565.63
4.00	26.76	97.00	188.50	230.10	338.40	407.11	460.00
10.00	20.58	61.00	96.10	118.60	195.63	202.38	235.00
15.00	17.76	40.16	65.30	89.21	90.41	85.71	80.00

APPENDIX - VII

Fresh weight of soybean plant (g/2 plants) at  
different time under different treatment.

Soil water potential (-bars)	Soil moisture content on weight basis(%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	4.61	8.02	14.86	17.52	19.36	21.81
1.20	30.00	3.97	6.70	12.52	15.32	17.60	18.76
4.00	26.76	3.70	5.45	10.56	14.88	16.10	17.18
10.00	20.58	2.41	3.83	5.29	8.16	8.34	9.10
15.00	17.46	1.50	2.05	3.50	4.10	4.38	4.50

APPENDIX - VIII

Dry weight of soybean plants (g/2 plants at different time under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis(%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	0.54	1.10	2.32	5.30	8.35	10.25
1.20	30.00	0.41	0.90	2.08	4.98	8.02	9.15
4.00	26.76	0.37	0.84	1.82	4.06	6.68	7.17
10.00	20.58	0.25	0.52	0.83	1.02	1.19	1.22
15.00	17.46	0.15	0.35	0.48	0.52	0.58	0.59

APPENDIX - IX

Fresh weight of soybean roots (g/2 plants) at different times under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis(%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	3.90	6.98	12.50	18.78	26.87	30.16
1.20	30.00	3.25	5.28	10.83	16.76	22.56	25.50
4.00	26.76	3.10	4.17	8.90	12.10	18.90	21.34
10.00	20.58	1.80	2.40	3.92	4.28	4.95	4.98
15.00	17.46	0.76	0.92	1.08	1.18	1.20	1.21

APPENDIX - X

Dry weight of soybean roots (g/2 plants) at different times under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	0.29	0.70	1.56	2.35	3.52	4.66
1.20	30.00	0.22	0.56	0.98	1.66	2.16	3.00
4.00	26.76	0.14	0.30	0.68	1.32	1.84	2.14
10.00	20.58	0.08	0.18	0.24	0.30	0.34	0.35
15.00	17.46	0.03	0.06	0.09	0.10	0.11	0.11

APPENDIX - XI

Shoot/root ratio (over dry weight basis) of soybean under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	1.86	1.57	1.49	2.25	2.37	2.19
1.20	30.00	1.86	1.61	2.12	3.00	3.71	3.05
4.00	26.76	2.64	2.80	2.68	3.07	3.63	3.35
10.00	20.58	3.12	2.89	3.46	3.40	3.50	3.48
15.00	17.46	5.00	5.83	5.33	5.20	5.27	5.36

APPENDIX - XII

Transpiration rate of soybean (g/cm<sup>2</sup>/day)  
under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	0.64	0.63	0.61	0.58	0.55	0.52
1.20	30.00	0.41	0.40	0.38	0.34	0.30	0.28
4.00	26.76	0.27	0.27	0.23	0.19	0.16	0.13
10.00	20.58	0.11	0.13	0.10	0.08	0.08	0.08
15.00	17.46	0.06	0.06	0.06	0.06	0.06	0.06

APPENDIX - XIII

Relative plant height of soybean  
under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	1.00	1.00	1.00	1.00	1.00	1.00
1.20	30.00	0.85	0.94	0.87	0.89	0.92	0.95
4.00	26.76	0.70	0.65	0.69	0.66	0.65	0.67
10.00	20.85	0.39	0.37	0.34	0.31	0.30	0.28
15.00	17.46	0.24	0.31	0.29	0.27	0.24	0.22

APPENDIX - XIV

Relative green leaf area of soybean  
under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	1.00	1.00	1.00	1.00	1.00	1.00
1.20	30.00	0.66	0.66	0.70	0.71	0.74	0.71
4.00	26.76	0.54	0.61	0.51	0.60	0.60	0.57
10.00	20.58	0.34	0.31	0.26	0.35	0.30	0.29
15.00	17.76	0.22	0.21	0.20	0.16	0.13	0.10

APPENDIX - XV

Relative fresh weight of soybean plant  
under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	1.00	1.00	1.00	1.00	1.00	1.00
1.20	30.00	0.86	0.83	0.84	0.87	0.91	0.86
4.00	26.76	0.80	0.68	0.71	0.84	0.83	0.78
10.00	20.58	0.52	0.48	0.35	0.46	0.43	0.41
15.00	17.46	0.32	0.25	0.23	0.23	0.22	0.20

APPENDIX - XVI

Relative dry weight of soybean plant  
under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	1.00	1.00	1.00	1.00	1.00	1.00
1.20	30.00	0.76	0.82	0.89	0.94	0.96	0.89
4.00	26.76	0.68	0.76	0.78	0.76	0.80	0.70
10.00	20.58	0.46	0.47	0.35	0.19	0.14	0.12
15.00	17.46	0.27	0.31	0.20	0.09	0.07	0.05

APPENDIX - XVII

Relative freshweight of soybean root  
under different treatments.

Soil water potential (-bars)	Soil moisture content on weight basis (%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	1.00	1.00	1.00	1.00	1.00	1.00
1.20	30.00	0.83	0.76	0.86	0.89	0.84	0.84
4.00	26.76	0.79	0.59	0.71	0.64	0.70	0.70
10.00	20.58	0.46	0.34	0.31	0.23	0.18	0.16
15.00	17.46	0.19	0.13	0.08	0.06	0.04	0.04

APPENDIX - XVIII

Relative dry weight of soybean roots under different treatment

Soil water potential (-bars)	Soil moisture content on weight basis(%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	1.00	1.00	1.00	1.00	1.00	1.00
1.20	30.00	0.76	0.80	0.63	0.71	0.61	0.64
4.00	26.76	0.48	0.43	0.43	0.56	0.52	0.46
10.00	20.58	0.27	0.25	0.15	0.13	0.09	0.7
15.00	17.46	0.10	0.08	0.06	0.04	0.03	0.02

APPENDIX - XIX

Relative transpiration rate of soybean under different treatment.

Soil water potential (-bars)	Soil moisture content on weight basis(%)	Days after start of experiment					
		7	14	21	28	35	42
0.33	34.40	1.00	1.00	1.00	1.00	1.00	1.00
1.20	30.00	0.65	0.63	0.62	0.68	0.54	0.53
4.00	26.76	0.42	0.42	0.37	0.32	0.29	0.26
10.00	20.58	0.18	0.20	0.16	0.13	0.14	0.15
15.00	17.46	0.10	0.09	0.09	0.10	0.11	0.11

APPENDIX - XX

Nutrient contents of the field (Average of three replications) before sowing.

Treatments	: Available :		: Available :		: Available :		: Available :		: Available :	
	: nitrogen (kg/ha)		: phosphorus (kg/ha)		: Potassium (kg/ha)		: Calcium (kg/ha)		: Magnesium (kg/ha)	
	: 0-15cm	: 15-30cm	: 0-15cm	: 15-30cm	: 0-15cm	: 15-30cm	: 0-15cm	: 15-30cm	: 0-15cm	: 15-30cm
N <sub>0</sub> (Control)	178.40	176.40	16.30	15.83	550.00	544.30	13370.70	13226.00	2576.00	2144.17
N <sub>20</sub>	180.20	178.20	14.60	14.13	548.30	543.30	13248.00	13010.00	2649.60	2239.00
N <sub>10</sub>	179.60	177.60	16.90	16.23	533.00	526.70	11776.00	11548.30	2281.60	1849.87
N <sub>6.7</sub>	179.60	177.60	18.30	17.27	522.30	516.70	12512.00	12292.70	2355.20	1956.60
N <sub>10</sub> FYM	181.30	179.30	18.80	17.80	519.00	513.30	12757.30	12535.30	2796.80	2333.87
N <sub>16.7</sub>	180.90	178.90	17.50	16.00	503.70	499.30	13002.70	12786.70	2649.60	2192.13
N <sub>20</sub> (½+½ FYM)	183.00	181.00	20.20	19.03	550.30	546.00	13616.00	13386.70	2428.10	1983.20
N <sub>20</sub> + Zn	178.80	176.80	19.30	18.13	532.00	526.30	12757.30	12456.00	2355.20	1922.43
N <sub>0</sub> (Farmer's control)	178.20	176.20	18.50	17.20	526.30	521.30	13002.7	12773.30	2428.80	1953.07
S.E m. ±	1.178	1.115	1.919	1.798	19.535	20.049	450.18	465.16	297.781	260.21
C.D. 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.D. 1%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
c.v.	1.134%	1.085%	18.642%	18.489%	6.00%	6.00%	6.00%	6.00%	21.00%	22.00%

APPENDIX - XXI

Nutrient contents of the field (Average of three replications) after harvesting.

Treatments	: Available : : Nitrogen (kg/ha) :		: Available : : Phosphorus (kg/ha) :		: Available : : Potassium (kg/ha) :		: Available : : Calcium (kg/ha) :		: Available : : Magnesium (kg/ha) :	
	0.15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
N <sub>0</sub> (Control)	180.90	175.13	12.20	12.00	473.70	445.7	11040.0	9445.30	2281.60	1766.40
N <sub>20</sub>	218.50	216.13	13.70	13.30	485.00	475.3	11040.0	9445.30	2355.20	1766.40
N <sub>10</sub>	198.37	194.27	16.20	15.70	477.30	469.0	9690.7	8832.00	1692.80	1472.00
N <sub>6.7</sub>	191.37	187.37	17.20	12.80	453.00	446.6	9936.0	9322.70	1766.40	1398.40
N <sub>10</sub> FYM	200.23	196.63	16.80	14.10	450.00	448.3	10058.7	9200.00	2208.00	2134.40
N <sub>16.7</sub>	213.10	210.40	16.70	13.90	492.70	482.00	10917.3	9813.30	2060.80	1913.60
N <sub>20</sub> ( $\frac{1}{2}$ + $\frac{1}{2}$ FYM)	221.63	219.33	14.00	16.30	499.70	490.0	11408.00	10426.70	1913.60	1766.40
N <sub>20</sub> + Zn	222.00	220.30	13.70	15.00	466.00	476.7	10794.7	9568.00	1840.00	1398.40
N <sub>0</sub> (Farmer's control)	180.17	174.77	14.70	14.40	455.00	450.0	10794.7	9077.30	1987.20	1619.20
S. Em. $\pm$	5.86	5.61	1.09	1.28	20.18	21.58	548.58	551.81	303.09	289.37
C.D. 5%	17.57	16.83	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.D. 1%	24.21	23.19	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V.	5.00%	4.88%	12.49%	15.70%	7.00%	8.00%	9.00%	10.00%	26.09%	30.00%

VIA

## VITA

The author of this thesis BRIJESH DIXIT was born on 26th April, 1963 at Patna (Raisen, M.P.). He received his Primary and Middle School education at Urdmau (Raisen) and Secondary education at Udaipura (Raisen). He passed his Higher Secondary School Certificate Examination of M.P. Board in year 1978. He secured throughout first division from Primary to Higher Secondary education.

He joined the J.N.K.V.V., Jabalpur in the year 1978 and successfully completed the degree of B.Sc.(Ag.) from the College of Agriculture Jabalpur in the year 1982. After graduation, he joined M.Sc.(Ag.) to specialize in Soil Science and Agricultural Chemistry, College of Agriculture, Indore (M.P.). He has completed his course with an O.C.G.A. 3.04 out of 4.00 scale. The thesis problem was assigned to him was of his choice, which has been completed by him and has been presented here with in the present form.

He is also a fine Poet, excellent Essay Writer, marvellous Debator and Classic Commentator of Cricket.