

## **Effect of Integrated use of Farmyard Manure and Inorganic Fertilizers on Soil Water Dynamics, Root Growth, Crop Yield and Water Expense Efficiency of Rainfed Soybean in a Vertisol**

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### **ABSTRACT**

The vagaries of monsoon is one of the major constraints for higher productivity of soybean in Central India. Efficient utilization of rainwater by modification of root architecture through different management practices holds promise for sustainable soybean production in this region. A field experiment was undertaken in a deep Vertisol at the Indian Institute of Soil Science, Bhopal during the year 2001-2002 to study the effect of combined application of farmyard manure (FYM) and inorganic fertilizers (NPK) to soybean (cvJS 335) on soil water dynamics, root growth characteristics, crop yield and water expense efficiency of soybean. The fertilizer dose used for soybean was N:P:K :: 30:26:25 kg ha<sup>-1</sup> and the rate of FYM application was 4 t ha<sup>-1</sup>. The results indicated that conjunctive use of NPK and FYM registered lower soil moisture storage in the profile, particularly during the period of water stress than NPK and control, which may be attributed to higher evapo-transpiration under NPK+FYM. The root mass of soybean was mostly confined to 15 cm soil depth. Combined application of NPK and FYM recorded 5.5% and 18.8% higher root length density (RLD) of soybean in the 0-15 cm soil layer at flowering stage over NPK and control, respectively. The root mass density (RMD) and root volume density (RVD) followed the trend similar to RLD. Application of FYM @ 4 t ha<sup>-1</sup> with NPK significantly improved the seed yield of soybean by 14% and 51.8% over NPK and control, respectively. The highest water expense efficiency (15.5 kg/ha-cm) was recorded under integrated use of NPK and FYM followed by NPK alone (13.7 kg/ha-cm) and control (10.8 kg/ha-cm). The higher productivity of soybean under NPK+FYM was thus attributed to improved root growth and efficient utilization of rainwater. Therefore integrated use of NPK and FYM bears potential for sustainable soybean production in Vertisol.

**Key words :** Soybean, FYM, Root length density, Root mass density, Root volume density, Matrix suction, Water expense efficiency.

Vagaries of monsoon is one of the major constraints responsible for lower productivity of soybean (<1 t ha<sup>-1</sup>) in Central India, the dominant soybean growing zone of the country (Damodaran and Hegde, 1999). Efficient utilization of rainwater through favourable modification of the root architecture by different management practices holds promise for sustainable soybean production in this region. In addition to erratic rainfall pattern, poor organic matter status of the soils of this region due to imbalanced nutrient management practices and low use of organic sources of nutrients by the farmers add to low productivity of soybean. Organic amendments help in improving the soil physical and biological environment besides supplying nutrients for crop growth (Darwish *et*

*al.*, 1995). Results from different studies revealed that continuous application of farmyard manure and green manure improved the soil organic carbon under different soils and cropping systems (Biswas *et al.*, 1971; Khilani and More, 1984; Swarup, 1998). Neither inorganics nor organics alone can maintain organic matter status of soil and sustain productivity (Prasad, 1996). So judicious uses of organic and inorganic fertilizers is essential to safeguard soil health and augment the nutrient use efficiency. Integrated use of organic and inorganic sources of nutrients can improve the root growth of soybean facilitating efficient utilization of stored soil moisture and nutrients from different layers in the profile, which will help in mitigating the adverse effect of water stress due to erratic rainfall

pattern and improve soybean productivity. The positive effect of integrated use of farmyard manure and inorganic fertilizers on productivity of soybean has been reported by many workers (Bobde *et al.*, 1998; Singh *et al.*, 1999; Hati *et al.*, 2000; Mandal *et al.*, 2000). There is a need to understand the effect of fertilizer and manure application on soil and plant processes, which will help in efficient management of these inputs for sustainable soybean production in this region. The present investigation was undertaken to study the effect of integrated use of farm yard manure and inorganic fertilizers on soil water dynamics, root growth characteristics, crop yield and water expense of soybean.

### Materials and Methods

The field experiment was carried out at the Indian Institute of Soil Science, Bhopal, Madhya Pradesh (23° 18' N longitude, 77° 24' E latitude and 485 m above mean sea level) during the year 2001 and 2002. The region has a hot sub humid climate with 1200 mm mean annual rainfall and 1400 mm mean annual evapo-transpiration. The soil of the experimental site is a deep Vertisols (Isohyperthermic typic Haplustert) with clay texture (52 % clay), bulk density of 1.34 Mg m<sup>-3</sup> at 0.27 g g<sup>-1</sup> soil water content, neutral to alkaline in reaction (pH=7.5), 4.4 g kg<sup>-1</sup> organic carbon, 0.3, dS m<sup>-1</sup> electrical conductivity and 46 c mol (p<sup>+</sup>) kg<sup>-1</sup> cation exchange capacity in the Ap horizon. The soil is low in available N (145 kg ha<sup>-1</sup>) and P (10.7 kg ha<sup>-1</sup>) but high in available K (325 kg ha<sup>-1</sup>). Rainfall received during the crop growth period in 2001 and 2002 were 766.6 mm and 638.3 mm, respectively.

The experiment was laid out with randomised block design with four replications. Soybean (cv. JS. 335) was grown as a test crop (under soybean-wheat rotation) during the *kharif* season of 2001 and 2002 with three nutrient management practices viz., T<sub>1</sub> : control (No fertilizer), T<sub>2</sub> : Recommended dose of fertilizer (N : P : K = 30:26:25 kg ha<sup>-1</sup>) and T<sub>3</sub> : Recommended dose of fertilizer plus farmyard manure (FYM) @ 4t ha<sup>-1</sup>. The crop was sown at the seed rate of 100 kg ha<sup>-1</sup> using tractor drawn seed-drill with a row spacing of 45 cm in the 2<sup>nd</sup> week of June in 2001 and in the 4<sup>th</sup> week of June in 2002.

Soil moisture content of the profile (0-90 cm) was determined thermo-gravimetrically at 15 days interval during the crop growth period in 2002 to study the distribution and redistribution of soil water in the profile. Matric potential in soil was measured *in situ* with the help of gypsum blocks installed at 7.5, 22.5 and 37.5 cm soil depth.

Water expense (WE) was computed by water balance method using the following equation:

$$WE = P + I - DS$$

Where

P = Precipitation

I = Irrigation

DS = Sf - Si

= Change in Soil Moisture Storage in the profile

Sf = Final moisture storage in the profile at harvest.

Si = Initial moisture storage in the profile at sowing.

Since soybean was grown under rainfed condition, I = 0

So, WE = P - DS

Water expense efficiency was estimated by dividing the seed yield of soybean with water expense.

Root samples were collected at flowering stage of soybean using root sampling cores (6 cm height, 8.6 cm diameter) up to a depth of 30 cm. After thorough washing and staining, root length was determined with the help of Delta T Scanner and image analysis system. The volume of these root samples was estimated by water displacement method. Then these root samples were dried in oven at 65°C till constant weight and the dry weight was recorded. The root length, mass and volume were divided by core volume to estimate root length density, root mass density and root volume density, respectively. The data were analysed by analysis of variance as outlined by Gomez and Gomez (1984).

## Results and Discussion

### Soil water dynamics

After sowing of the crop there was a dry spell for about one month (Fig. 1). Further at the grain filling stage there was withdrawal of monsoon, which hampered crop growth and yield. The distribution of rainfall was reflected in the temporal changes in the soil water storage in the profile (0-90 cm) (Fig. 2). It is noteworthy that in many instances, the moisture content of the profile has gone below 15 bar suction but the crop could survive. This is a typical characteristic of Vertisol where substantial amount of water is released even beyond 15 bar suction, the classical upper limit suction for plant available water, which is utilised by rainfed crops (Kauraw, 1982). It was observed that conjunctive use of NPK+FYM registered relatively lower soil moisture storage in the profile than NPK and control (Fig. 2). This was attributed to the higher evapotranspiration under NPK+FYM because of better crop growth in the presence of FYM in this treatment (Hati *et al.*, 2000). The positive effects of integrated use of NPK and FYM on evapo-transpiration was attributed to the stimulation of above and below ground biomass because of availability of higher amount of nutrients in this treatment leading to more interception of incoming solar radiation. This results in higher transpiration demand while at the same time more soil water was made available through root proliferation (Corbeels *et al.*, 1998). The differences in the soil moisture storage due to

nutrient management were more conspicuous during dry spell. The distribution of moisture content the profile (Fig. 3) depicts that difference in the moisture content due to nutrient management was more prominent in the upper layer than in the lower layers which emphasizes higher moisture extraction from upper layers because of higher root density in those layers. Crops under NPK+FYM extracted more water from the soil profile than that under NPK and control.

The temporal changes in the matric suction at different soil depths during a dry spell between 75 and 95 days after sowing have been depicted in Fig. 4. Matric suction was higher under lower moisture content in the profile and it decreased with increase in the moisture content in the profile. During the dry spell the matric suction increased with time, which emphasizes gradual increase in moisture extraction from the profile with advancement of crop growth. The matric suction declined with increase in the soil depth indicating higher moisture content at lower depth. It was observed that among the three nutrient management practices NPK+FYM registered the highest matric suction up to 37.5 cm soil depth, which was supported by lower moisture content in the profile in this treatment (Fig. 4), which was supported by lower moisture content in the profile in this treatment (Fig. 3). It is interesting to note that in control the matric suction was higher in the surface layer (0-15 cm) than NPK, which may be, attributed to higher evaporation loss in control due

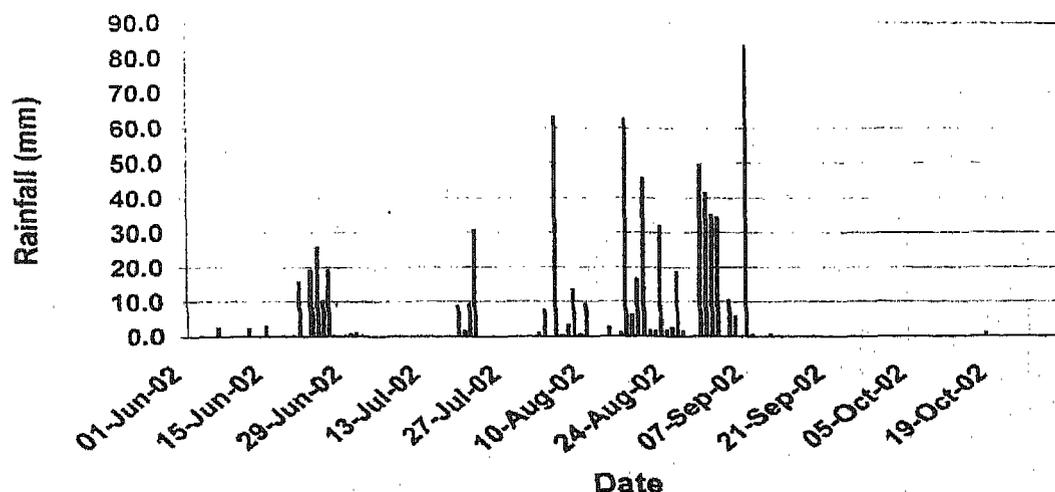


Fig. 1. Rainfall distribution pattern during soybean in 2002

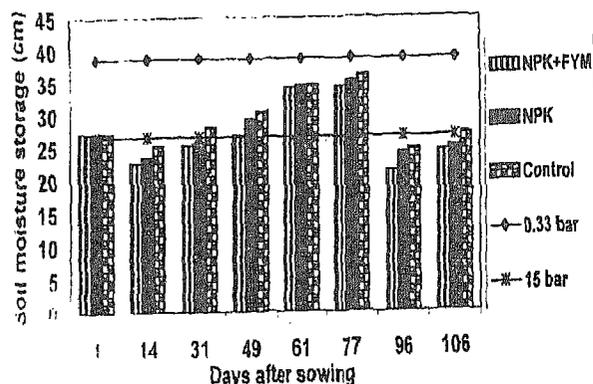


Fig. 2. Temporal variation in the soil moisture storage in the profile (0-90 cm) during soybean growth

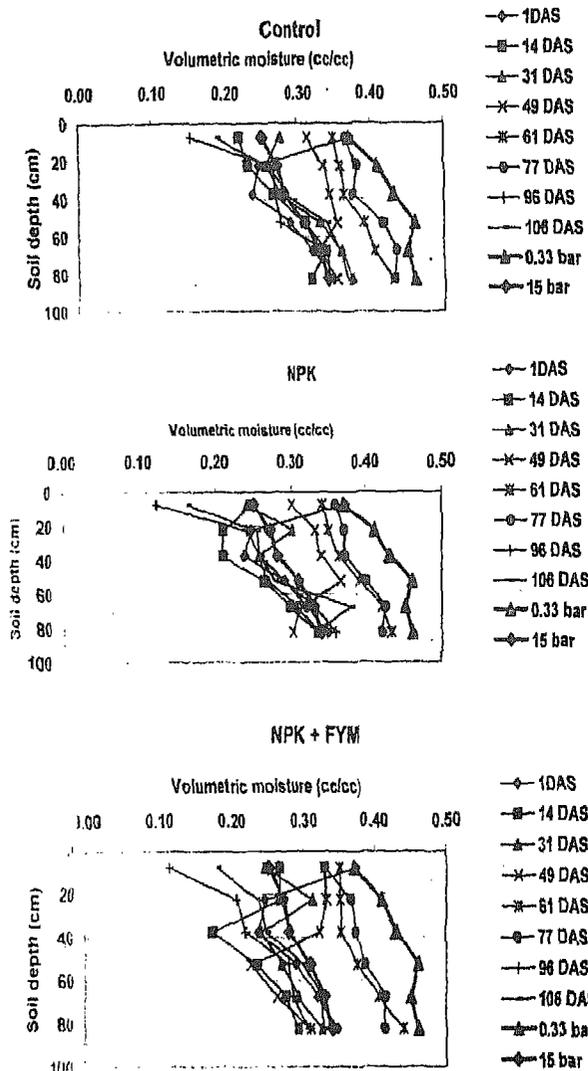


Fig. 3. Temporal changes in the volumetric moisture content in the profile during soybean growth as influenced by three different nutrient management

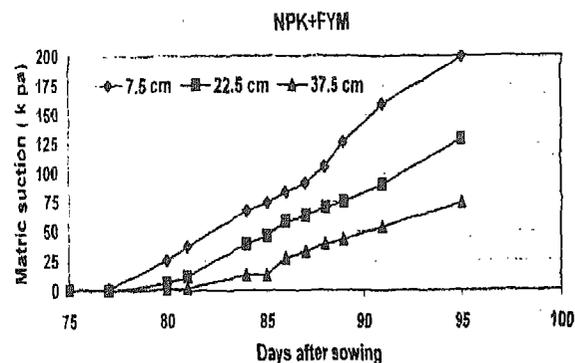
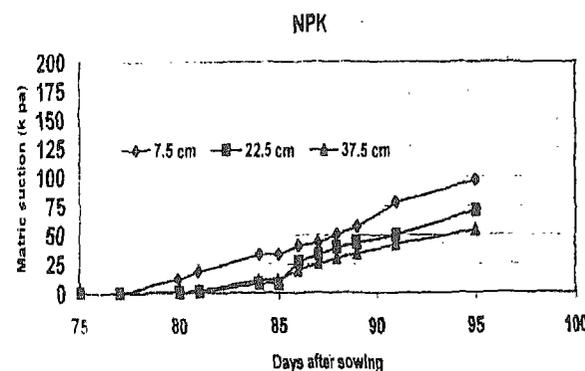
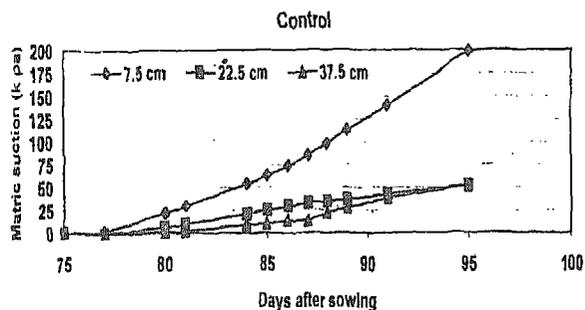


Fig. 4. Temporal variation in the matric suction of the profile during soybean growth under three different nutrient management

to lower foliage cover. It was observed that leaf area index in control was less that of NPK and NPK + FYM (Data not presented). However after 84 days after sowing the matric suction in the sub surface layer under NPK surpassed the matric suction in those layers under control because of better moisture extraction with NPK through better root proliferation than control in those layers.

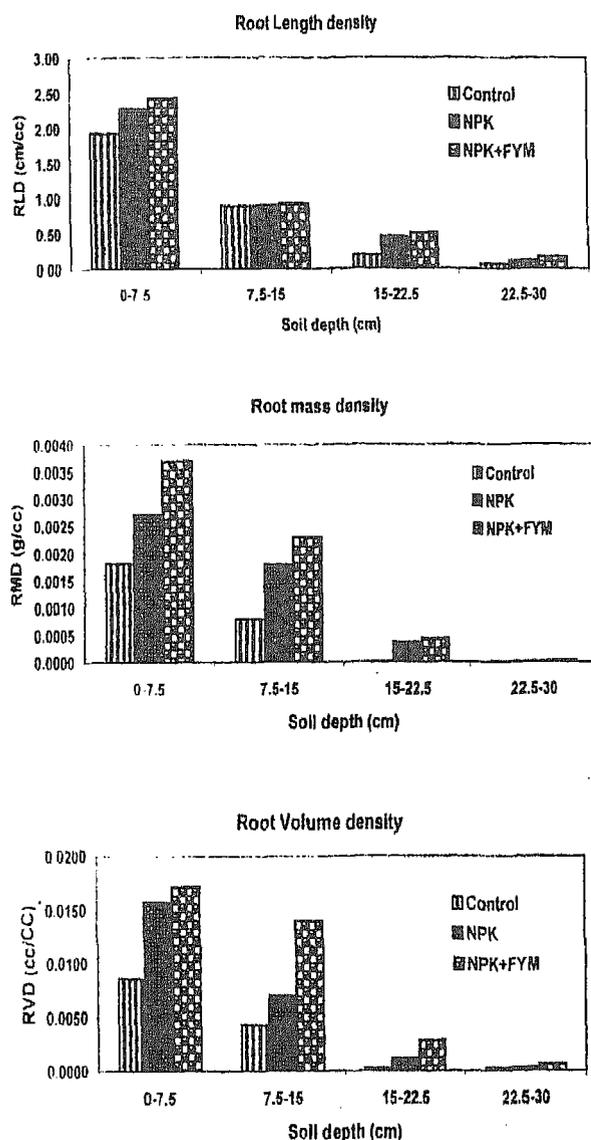


Fig. 5. Root densities of soybean at flowering stage

### Root growth

Integrated use of NPK and FYM improved the root length density (RLD) of soybean up to 30 cm soil depth than NPK and control (Fig. 5). This may be attributed to better nutrient supply and creation of better physical environment in the presence of manures. It was observed that NPK+FYM recorded 5.5% and 18.8% higher RLD than NPK and control, respectively in 0-15 cm soil layer. Combined use of NPK and FYM also improved the root mass density (RMD) and root volume density (RVD) over NPK and control. The root mass of soybean was mostly confined to 15 cm soil depth. There was decline in the RLD, RMD and RVD of soybean with depth. However, the rate of decline in RMD and RVD with depth was more than that of RLD, which indicates that the finer roots of soybean were mostly confined in deeper layers. Allmaras *et al.* (1975) also reported higher root length/weight ratio of soybean at greater depths in soil profile.

### Crop yield and water expense efficiency of soybean

Fertilizers and manure application significantly improved the seed and stover yield of soybean over control (Table 1). Application of FYM @ 4 t ha<sup>-1</sup> along with recommended dose of fertilizers (NPK) significantly improved the seed yield of soybean by 14 per cent over NPK and by 51.8 per cent over control. The higher seed yield of soybean in NPK+FYM is attributed to better root growth and efficient utilization of water in this treatment than NPK and control. This was evident from

Table 1. Seed yield, stover yield and Water Expense Efficiency (WEE) of soybean in the year 2001 and 2002 as influenced by integrated nutrient management

Treatment	Seed yield (kg ha <sup>-1</sup> )			Stover yield (kg ha <sup>-1</sup> )			WEE (kg / ha-cm)		
	2001	2002	Mean	2001	2002	Mean	2001	2002	Mean
Control	726.7	651.7	689.2	1559.8	1651.3	1605.6	11.5	10.20	10.8
NPK	946.4	885.6	916.0	1966.8	2353.5	2160.2	14.0	13.40	13.7
NPK+FYM	1110.4	982.0	1046.2	2309.4	2560.2	2434.8	14.7	15.50	15.5
LSD (5%)	97.1	61.2		262.0	102.8				

higher water expense efficiency under NPK+FYM (15.5 kg/ha-cm) than NPK (13.7 kg/ha-cm) and control (10.5 kg /ha-cm). Sharma (1997) has reported higher yield and water use efficiency of soybean under integrated use of fertilizers and farmyard manure in Vertisol. The stover yield of soybean followed similar trend as that of grain yield of soybean. The seed yield of soybean in 2002 was lower than that of 2001, which may be attributed to better rainfall distribution pattern and higher rainfall receipt in 2001 (766.6 mm) than in 2002 (638.8 mm).

Thus from the present investigation it may be concluded that integrated use of farmyard manure and chemical fertilizers may be practised in Vertisols for achieving higher productivity of soybean through better root growth and efficient utilization of soil water.

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