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Title: Long term fertilization effects on root parameters of maize (Zea Mays) crop in an acid Alfisol

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Abstract - Field studies were conducted in a 29 year long-term fertilizer experiment on silty clay loam soil to study the effect of long-term fertilizer application and amendments on root development and cation exchange capacity of maize roots during 2001-02 at CSKHPKV, Palampur, Himachal Pradesh, India in an acid alfisol of western Himalayas. Integrated use of inorganics and organics resulted in marked increase in root mass density, root volume and rooting length after harvest and root cation exchange capacity at various crop growth stage of maize crop. The highest CEC was observed at Knee high stages of maize crop. Lime application along with balanced fertilizer application induced favourable conditions for root growth by neutralizing acid soils to greater extent. Application of 100% of recommended doses of Nitrogen alone, restricted the rooting depth bringing the cation exchange capacity at zero levels.

Index Terms: long-term fertilizer experiments, root length, root volume, root mass, maize, nitrogen, liming

INTRODUCTION:

Maize –wheat is the major cropping system of Himachal Pradesh contributing about 85% of the total share of the food grain production. Therefore raising the viability of this cropping system holds key to transformation of agriculture scenario in the State. Unfortunately, the continued use of imbalanced fertilizers and nutrients has led to drastic reduction in production levels with simultaneous negative effect on sustainability and acidity of productive soils.

Capability of plants to exploit nutrients and water from the soil depend on the root morphology in terms of root depth, root branching, number of root hair, root tip etc. Root studies are of significance due to its main three functions as anchoring the plant in the soil, absorption and translocation of water and nutrients and synthesis of phytochromes and other organic compounds (Mengel and Kirkby, 1987). Root studies are not easy due to complication in the measurement of root system and root parameters. The great ability of plants to absorb nutrients from soil, generally credited to the excretion of carbonic acid is most easily accounted by the formation of strong acidoid (H-colloid) in the root surface. Significance of exchange capacity of roots (RCEC) of the crop plants has been well documented in various theories and in assessing the fertility status and health of soils besides explaining cation accumulation or depletion in soils and prediction of plant composition and grain yields studying the mobilizing the plant nutrients from the insoluble primary and secondary minerals (Singh and Singh, 1981). However, studies exhibiting the effect of continuous fertilization and manuring on these root parameters in acid soils of western Himalayas is lacking and it is in this context, the attempt has been made to undergo this study under the auspices of All India Coordinated Research Programme of long-term fertilizer experiment in maize-wheat cropping sequence.

MATERIAL AND METHODS:

A field experiment (randomized block design with four replicates) on an Alfisol (17.8 % clay, 76.3 % silt, 5.9 % sand) comprising 10 treatments was established in 1972- 73 at the experimental farm of the College of Agriculture, Palampur. With soil characteristics as silty clay loam in texture, acidic in reaction (pH 5.8), medium in organic carbon (7.9 gkg-1), high in N (736 kg ha-1), and medium in P and K (12 and 194 kg ha-1, respectively).The bulk density was 1.31 Mg m-3 with moderate rapid permeability. The treatments were Control (T1), 100% N (T2), 100% NP (T3), 100% NPK (T4), 100% NPK + farm yard manure (T5), 100% NPK + lime (T6), 100% NPK + Zn (T7), 100% NPK + hand weeding (T8), 50% NPK (T9) and 150% NPK (T10). The 11th treatment comprising of 100% NPK - S (T11) was introduced in kharif 1980. Zinc was applied in T7 as zinc sulphate at the rate of 25 kg ha-1 every year to both the crops. Farmyard manure (FYM) application was made at the rate of 10 t ha-1 on fresh weight basis to the maize crop only, which corresponded to the practice being followed by the farmers of the region. Lime was applied (T10) at the rate of 900 kg ha-1 as marketable lime ($CaCO_3$) passed through 100-mesh sieve only to maize crop every year till the soil pH rose to about 6.5. 100 per cent NPK application rate corresponded to the state level recommendation for

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respective nutrients. The sources of N, P and K were urea, single super phosphate and murate of potash at the rate of 120, 60 and 40 kg ha-1. In the case of 100% NPK-S, the P was applied through diammonium phosphate (DAP) to assess the effect of 'S' free high analysis P fertilizer in crop production.

Root studies were carried out at various stages viz. knee high, tasseling, after harvest stages of maize crop. The root samples were taken by core break method (Bohm, 1979) to a depth of surface layer (0-0.15 m). Root length was computed using the modified version of Newman (1966) formula proposed by Marsh (1971) and Tennant (1975) as:Root Length (R): 11/14 *number of intersections (N) *grid unit

The grid unit was combined with 11/14 factor, which gave a factor of 0.786 for one grid square.

Total root length was divided by the volume of the core to compute root length density and was measured inmm-3 X 10-4

Root volume was determined by displacement method (Mishra and Ahmed, 1987) and divided by the volume of the core to compute root volume per unit volume of soil. The fresh weight of roots was divided with the volume of the sampling core to compute root weight density in kg m-3 (Mishra and Ahmed, 1987).

The oven-dried weight of roots extracted at different crop growth stages was recorded and the root CEC was carried out by the method of Crooke (1964).

RESULTS AND DISCUSSION:

Root Mass Density (RMD): The RMD was determined after the harvest of 29th maize crop (kharif 2001). The highest root mass density (10.02 kg m-3) was observed in the plots receiving farm yard manure once in a cropping cycle for twenty nine years in combination with recommended level of NPK (Fig 1). The FYM and lime treated plots increased the RMD by 55 and 93 per cent, respectively over the plots receiving zero fertilization. This may be attributed to the efficient utilization of nutrients by the crop in the presence of organic matter resulting in more proliferation of roots (Rajput et al., 1984; Cadisch et al., 1993; Acharaya et al., 1998). Graded doses of chemical fertilizers had almost synergistic effect on root distribution in maize crop due to long-term fertilization.

An increase in the bulk density values in 100 per cent N alone treatment continuously for twenty-nine years, on the other hand resulted in no root growth due to withering of crop at later stages (Tasseling and Harvest) of crop growth and as such, no root mass due to deterioration of soil structure.

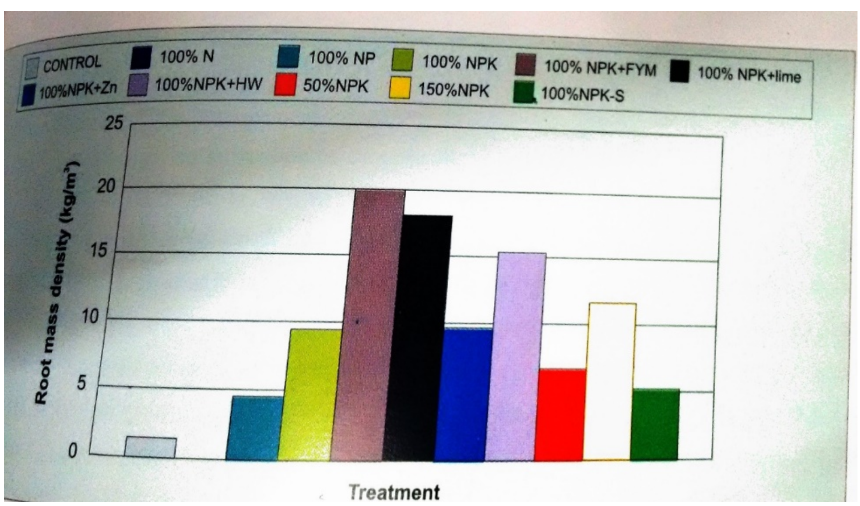

Fig 1. Effect of Long Term fertilization on Root Mass Density

Root volume: The root volume of maize at harvest was comparatively higher in the plots receiving zero fertilization in comparison to the plots receiving 100 % N alone for a period of twenty-nine years (Figure 2). Root extension and proliferation were discernible to greater extent more with the application of FYM in combination with inorganic fertilizers. The highest rooting density (25.6m3m-3x10-3) was recorded in the 100 per cent NPK+FYM treated plots. This could be easily explained on the grounds that the soil under FYM treated plots was more

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porous and well pulverized, so it exhibited low soil resistance to root penetration, thereby upgrading these two parameters. Another possible explanation is that organic matter also helps in maintaining the ideal soil temperature, moisture and aeration essential for proper root distribution due to its high buffering capacity that results in improved root mass as well as root volume densities of the soil (Acharya et al., 1998). Profuse growth of secondary roots as well as root hair by the addition of organic amendments (FYM) might be another important reason for the upgradation of root volume compared to rest of the treatments.

The increasing levels of NPK to 150 per cent showed synergistic effect on root distribution and hence root volume. The increase in the root volume in 150 per cent NPK treatment was observed to be 4.55 m3 m-3 x10-3 over unmanured plots. The use of 100 per cent NPK + lime increased the root volume by 148.6 percent over the use of 100 per cent NPK alone (Fig 2).

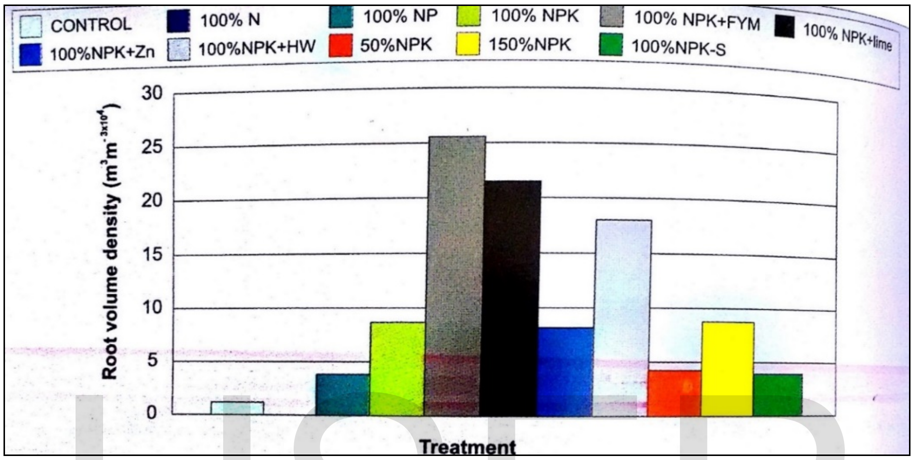

Fig 2. Effect of Long Term fertilization on Root Volume Density

Rooting Length: The rooting length in each of the treatment was worked out as root length density. The highest rooting length of 2.48 m m-3 x 104 was observed in the plots receiving FYM once in a cropping cycle in combination with recommended level of NPK for twenty-nine years (Figure 3). This may be attributed to the efficient utilization of the nutrients in the presence of organic matter for better proliferation of roots. These conditions increased the availability and absorption of applied N favorable for the development of seminal and coronal roots of the corn crop (Cadisch et al., 1993, Acharya et al., 1998). Liming increase the calcium levels in the soil which enhanced the root penetration of the crop in deeper layers (Raychaudhary et al., 1998). The plots treated with 100 per cent N alone, on the other hand, did not show any root growth which might be due to the severe deficiency of P, low organic matter, high soil strength and poor soil aeration essential for root distribution. Also, leaching losses of N might have rendered its non-availability for root growth. These results are in agreement with the findings of number of workers (Mengel and Kirkby, 1987; Acharya and Sharma, 1994; Mishra and Sharma, 1997).

The lime application and the use of 100 per cent NPK+HW also showed increase in the rooting length of maize crop in comparison to the plots receiving only 100 per cent NPK (followed by chemical weed control measures). The use of chemical fertilizers at higher levels (T10) showed about 95 per cent increase in the rooting length in comparison to the recommended level of NPK (T4). The omission of K (T3) and S (T11) in plant nutrition also showed reduced rooting length compared to the recommended level of NPK (Fig 3).

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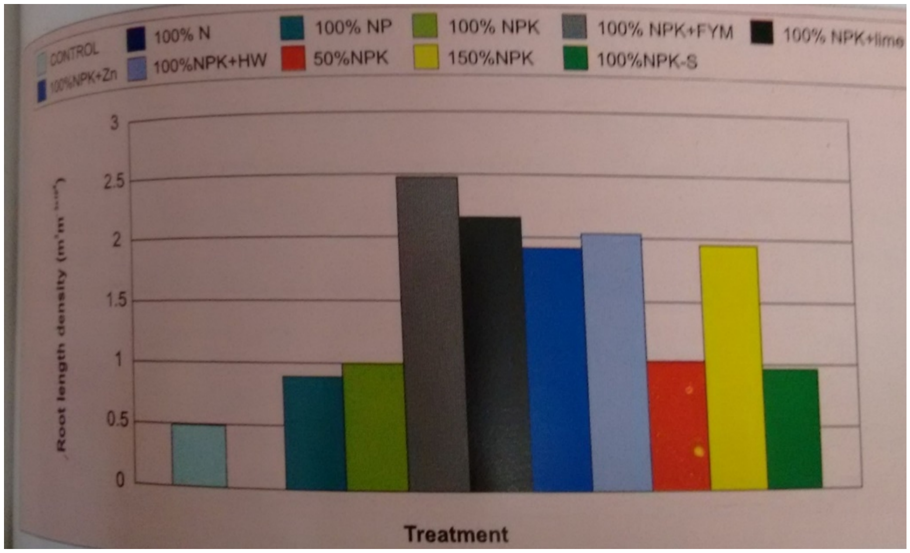

Fig 3. Effect of Long Term fertilization on Root Length Density

Root cation exchange capacity [RCEC]: The root CEC was determined at the knee high, tasseling and at after harvest stage of the maize crop. The root CEC values were found to be highest at initial stage of maize crop growth and decreased with the advancement of crop towards maturity as root growth partially ceases after flowering.

The highest root CEC (30.50 c mol p+ kg-1) was obtained at the knee-high stage with the application of FYM along with 100 % NPK followed by the plots treated with 100 per cent NPK (26.0 c mol p+ kg-1) after kharif 2001 (Table 1). These findings are in line with the reports of many workers (Drake et al., 1951; Helmy and Elgabaly, 1958; Singh and Singh, 1981; Gupta, 1985). The higher root CEC at initial crop growth stage and low with the advancement in crop growth may be attributed to the greater abundance of pectin substances in young tissues and decrease to the extent of 0.5 to 1.5 per cent with the maturity of the tissues (Gupta, 1985). Further, the thickening of the cell wall to a lesser extent in initial stages of plant growth and to a greater extent at maturity may also be the possible reason for higher root CEC at initial stages of crop growth (Mane et al., 1970).

TABLE 1

EFFECT OF CHEMICAL FERTILIZERS AND AMENDMENTS ON CEC OF MAIZE ROOTS

Treatments	(Root CEC (c mol p+ kg-1)		
	Knee high	Tasseling	After harvest
Control	16.0	10.0	5.2
100% N	19.0	0.0	0.0
100% NP	18.0	16.0	13.8
100% NPK	26.0	18.0	14.5
100% NPK+FYM	30.5	21.2	17.0
100% NPK+lime	25.0	17.0	14.8
100% NPK+Zn	20.0	15.5	10.1
100% NPK+HW	24.0	14.5	11.7
50% NPK	21.0	15.0	6.9
150% NPK	23.0	12.5	10.9
100% NPK-S	16.5	12.5	6.3
CD (p=0.05)	7.35	3.28	5.15

The application of graded doses of chemical fertilizers had almost comparable effect on the root CEC of maize crop. However, continuous cropping in the 100 per cent N alone treated plots resulted in extreme limitation of rooting depth, thereby reducing the capacity for exchangeable bases in roots of both maize and wheat crops to zero level.

Lime application in combination with chemical fertilizers (T6) was at par with that of organically amended plots (T5). The increase in root CEC due to liming could be attributed to its effect on soil properties that become more favourable for growth and development of roots resulting in an increased root CEC (Haurigan et al., 1961).The per cent increase in the root CEC values under 100 per cent NPK + FYM treatment in the maize crop (twenty-ninth cropping cycle) was about 50 per cent over unmanured plots. This could be attributed to the fact that organic matter helps in making the soil porous and pulverized which ensures better root development thereby, increasing the root CEC (Mehrotra and Saxena, 1970; Singh and Ram, 1976).

CONCLUSION: Application of FYM with recommended doses of chemical fertilizers have proved to have beneficial effect on growth and proliferation of root growth of maize crop in the present study. Root cation exchange capacities had their maximum values under organically amended plots (100% NPK+FYM) followed by lime treated plots due to availability of ideal soil environment essential for root growth. The application of 100% N alone had led to complete deterioration of soil structure, thereby no root growth was observed. Treatment with graded doses had almost comparable effect on root CEC of the crop. Root weight was found to be poor parameter over rooting length density as old and thick roots may contribute much to weight while playing minor role in nutrient and water uptake.

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