

Original Research Article

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Dynamic Changes in Soil Physico-Chemical Properties with the Application of Inorganic Fertilizers

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ABSTRACT

Imbalanced application of inorganic fertilizer generates undesirable over soil physicochemical properties to a great extent. Short term aerobic incubation experiment was implemented with soil samples (Typic Haplustert) collected from top soil horizon (0-15cm) of cabbage field in Viraliyur, Coimbatore district of Tamil Nadu. Intention of study is towards examining the pattern of changes in pH and electrical conductivity (EC) in soil added with varied levels of fertilizers (NPK) under field capacity condition. Fertilizer was applied in accordance with the treatments viz., control (no fertilizer), 100 % of RDF (100:125:25), 125% of N + Recommended PK, 150% of N + Recommended PK, 125% of P + Recommended NK, 150% of P + Recommended NK, 125% of K + Recommended NP, 150% of K + Recommended NP. Fertilizers source used were urea, diammonium phosphate (DAP) and muriate of potash (MOP). Experimental soil was characterized for its physico-chemical. The pH was neutral in reaction and EC level was in safer limit. Incubation period was extended for two months. Destructive sample from each set of container was taken at weekly intervals for analysis of pH and EC. From the experimental results, no significant changes in the pH and EC were recorded during the first three weeks of incubation. The acidification was most pronounced in soil receiving urea at 125 and 150 per cent recommended level. The slight change in pH and electrical conductivity was noticed after third week of incubation. A prominent change in soil reaction was induced by the urea applied at the rate of 150% + Rec PK in comparison with other treatments. Salinity levels was greatly influenced in the DAP treated soils.

Keywords

Soil pH, Electrical Conductivity (EC), Fertilizers

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Introduction

Indispensable element of agriculture is soil and its inherent component evidently affects its agricultural value (Kieth *et al.*, 2012). Agronomic technologies, which include fertilization practices, have a considerable, although not continually optimistic effect on soil residences (Naima *et al.*, 2015). Over the past years the excessive, frequently

uncontrolled and routine use of mineral fertilizers had a very adverse effect on soil chemical, physical, particularly biological traits and yield efficiency (Milosevic *et al.*, 1995). Utility of mineral fertilizers within the soil has several effects on the residences of the soil, as an example salinity values and soil pH.

Soil serves as storage reservoir for nutrients and water obligatory for plant growth. Crop

production potential is greatly influenced by soil physical and chemical properties (Su *et al.*, 2002). Agronomic practice including chemical fertilization had a great influence over soil physico-chemical properties.

Average nutrient input–output balances significantly reduced from the 1990s; most soils in Tamil Nadu are sufficiently or even highly supplied with plant-available nutrients. This “legacy excess fertilizers” poses high and long-term risks to soil and water bodies (Sharpley *et al.*, 2013). However, continued long term application of fertilizers can lead to accumulation in surface horizons greater than that required for optimum plant growth, thus increasing the potential for nutrient loss to surface waters and eutrophication (McDowell *et al.*, 2001).

Application of such mineral fertilizers in the soil has several effects on the properties of soil, for example changes in soil salinity and soil reaction. It reflects the overall chemical status of the soil and influences a whole range of chemical and biological processes occurring in the soil. Because of its implications in most chemical reactions in the soil, knowing the actual value of soil pH and monitoring its changes is critical for understanding the physicochemical functioning of the soil (Jaillard *et al.*, 2003).

With current levels of inorganic fertilizer used, the potential for fertilizers to have negative impacts on productivity and environmental quality is great, leading to productivity declines and environmental problems (Ogbodo, 2013).

Keeping the above points in view an incubation experiment with varied NPK levels was conducted to investigate the changes on soil reaction and electrical conductivity.

Materials and Methods

Laboratory incubation study was conducted in silty loam soil to assess the changes in soil reaction and EC as influenced by NPK fertilizers applied at varied levels. The experiment was carried out with completely randomized design replicated three times. The experimental set up was maintained for eight weeks. The fertilizer treatments comprised of: T₁ – Control; T₂ – 100 % RDF; T₃ – 125% N + Rec PK; T₄- 150% N + Rec PK; T₅- 125% P + Rec NK; T₆- 150% P + Rec NK; T₇- 125% K + Rec NP; T₈- 150% K + Rec NP. Recommended fertilizer rates for cabbage were 100:125:125 kg of NPK ha⁻¹. Straight fertilizers viz., Urea, DAP and muriate of potash were applied for N, P and K respectively. The study focused on the consequence of changes in soil reaction and EC by NPK fertilizers at varied levels in soil moistened at field capacity level.

Preparation of Soil Medium

The soil was collected from the upper layer of surface horizon at a depth of 0-15 cm at five sampling points randomly selected from cabbage grown farmer’s field in Viraliyur, Coimbatore District. The sample was air dried, processed through 2mm sieve and homogenized.

Polythene containers each carrying 100 g of processed soil with a capacity of 100 ml were arranged in completely randomized design with three replicates. Required quantity of water was added to maintain the soil moisture at field capacity throughout the period of incubation (2 months) and the cups were kept open at room temperature. Soil moisture was monitored at 3 days intervals based on the weight of the cups and maintained at field capacity by the addition of distilled water.

Analysis of soil for releasing pattern of nutrients

Destructive sample from each set of container was utilized for analysis at weekly intervals. Samples were estimated for physico-chemical properties. pH was measured in a 2:1 water/soil ratio with a shaking time of about 30 minutes (ELICO – LI615 pH meter). Salinity was determined by measuring the electrical conductivity of the saturated soil extract given by Jackson (1967) EC (ELICO CM 180 Conductivity meter).

Results and Discussion

Initial characteristics of soil used in the study

The composite soil collected from field was neutral in reaction and non-saline. The textural analysis revealed that it is silty clay loam in nature. The physical properties *viz.*, bulk density, particle density, porosity and water holding capacity were 1.35 (Mg m^{-3}), 2.64 (Mg m^{-3}), 47.3 per cent and 40.1 per cent respectively. Organic carbon status was medium and the exchange reactions of soil in respect of cations were 13.4 $\text{cmol (p}^+) \text{ kg}^{-1}$. Available nutrient status of soil with respect to N, P and K showed high K (230 kg ha^{-1}), medium P (18 kg ha^{-1}) and low N (195 kg ha^{-1}).

Soil reaction affected by fertilizers

N fertilizer on soil pH

Fate of chemical fertilizer use and its consequence on soil pH in acid, neutral and alkaline soil depends primarily its nature *viz.*, acidic, alkaline, neutral and types (straight, complex or compound) and obviously its components.

The results revealed that, there was a temporary changing effect in pH was noticed in urea treated soil. Initially the soil pH was neutral (7.6) in reaction. In 100 % NPK treated soil; the pH was increased from 7.6 to 8.2 and the escalating trend was seen up to 28 DAI with the highest pH of 8.2 recording during third week of study (Fig. 1). When the soil is high in carbonate content, the pH may not drop even though soil is added with acidic fertilizers (Glendining *et al.*, 2017). In this case, the experimental soil with high carbonates content might be a factor for such increasing trend in pH. With increasing period, inclination pattern declined and reached its stability toward its initial soil reaction at the end. The degree of change in soil pH on urea application depends on the buffering capacity of the soil.

Among the treatments, N applied @ 125% and 150% excess than the recommended dose influenced the soil pH much more than other treatments. In 125% N + Rec. PK, the pH gets reduced within 7 DAI from 7.6 to 7.3 and further it was raised and reached a maximum of 7.9 at 42 DAI. After this period, the pH started declining and attained near initial range of 7.7 (Fig. 2a). The soil treated with 150% N + Rec PK has also reduced soil pH as in 125%N applied soil. But in this case the reduction in pH was observed up to two weeks *i.e.*, 14 DAI. The highest decline of 7.2 was also recorded in 150% N treated soil in accordance with the other fertilizer treatments (Fig. 2b). This is in line with the findings of Wells *et al.*, (2014) who observed that, higher the dosage of urea resulted in maximum reduction of soil pH. Thereafter the pH got raised and attained its stability at the end of the incubation. Hydrolysis of urea resulted in bicarbonate and ammonium-N formation and the bicarbonate ions then reacted with H^+ ions in the soil solution, which temporarily

might have reduced acidity, but acidity is again produced when ammonium-N undergoes nitrification (Wardle, 1992). After decline, gradual increase in the pH was recorded and the same trend was seen up to 42 DAI in 150% N treated soil (Fig. 2b). Stability in the soil pH was observed at the end of the incubation. In case of NH_3^+ liberation the soil pH will get increased but when it get lost or transformed to nitrate, the soil pH decreased. Urea is typically a fertilizer with acidifying nature in soil and nitrogenous fertilizers could decrease the soil pH. This acidifying effect of nitrogenous fertilizers is in agreement with the findings of Hati *et al.*, (2008) and Darusman *et al.*, (1991), who also reported a decline in soil pH with application of nitrogenous fertilizers. This is mainly due to the fact that most fertilizers supply N as NH_4^+ first, which upon oxidation releases H^+ ions (Magdof *et al.*, 1997).

Free hydrogen (H^+) ions increase the acidity. Higher the percentage of ammonium in the fertilizer results in greater acidification potential. Ammonium-based fertilizers will acidify soil as they generate two H^+ ions for each ammonium molecule nitrified to nitrate (Lu *et al.*, 2012). Moreover urea on hydrolysis leads to concomitant rise in soil pH due to the formation of easily decomposable ammonium carbonate that readily liberates ammonia (Erikson *et al.*, 1985). Hence the significant effect of varied urea levels on soil reaction was observed when increasing the levels of N during period of incubation.

P fertilizer on soil reaction

There is a correlation between salt concentration and soil pH with a pH decrease accompanying salt leaching from the soil profile. In case of P fertilizer except DAP most of the P fertilizers are acidic in nature

and P can get adsorbed in both acidic/slightly alkaline conditions (Richards, 1969; Singh *et al.*, 2007). The DAP, a salt of weak base which upon hydrolysis reaction of phosphate anion produces OH ions. Therefore the initial pH of soil due to application of this sort of fertilizer is slightly basic.

The DAP used in the study which is alkaline in nature and applied at a rate of 100%, 125% P + Rec NK and 150% P + Rec NK. Application of DAP did not have much influence in altering soil pH in spite of its less acidifying potential. The soil applied with 125% P reduces pH to small units from 7.6 to 7.55. From second week onwards irregular pattern of changes in soil pH was observed till end of the incubation period (Fig. 3a).

The form of P in diammonium phosphate (DAP) is HPO_4^{2-} which can make acidic soils ($\text{pH} < 7.2$) more alkaline but has no effect on soil with a $\text{pH} > 7.2$. Though the initial pH (neutral) on application of phosphate fertilizers may differ but after a few days or few weeks the differences may disappear.

Therefore, phosphate fertilizers may not alter soil pH conspicuously (Adhikari *et al.*, 2014). The ammonium present in DAP is gradually converted to nitrate by soil bacteria, resulting in a subsequent drop in pH. Among all the treatments except 100 % NPK treated soil, 150% P + Rec NK increased the pH from 7.6 to 7.7 and sudden turn down was noticed and the pH got reduced to the lowest level of 7.43 at 35 DAI (Fig. 3b).

This may be due to that at higher level (150%) of P application higher ammonium would have been converted to nitrate along with H^+ ions (Naima *et al.*, 2015). At the end of the period the pH attained stable condition and it got reduced from its initial value.

Fig.1 Pattern of change in the soil reaction by 100% NPK fertilizer during period of incubation

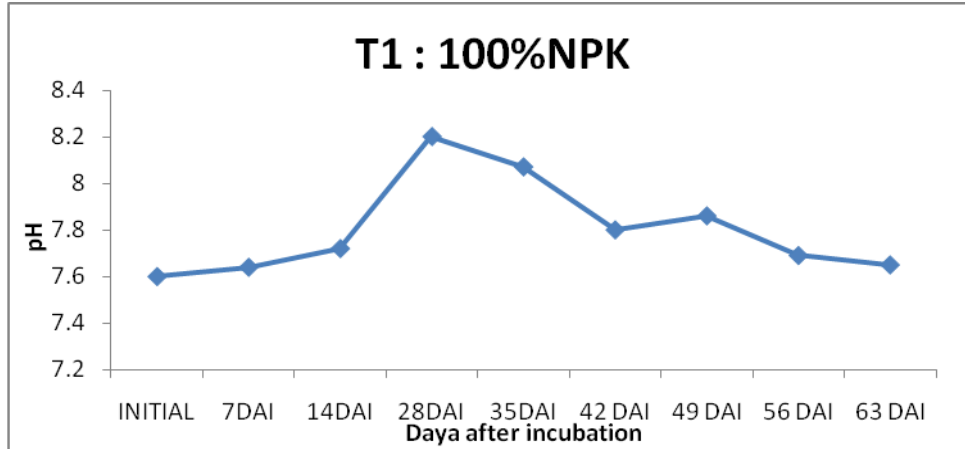


Fig.2a Pattern of change in soil reaction changing pattern by 125 % N + Rec. PK fertilizer during period of incubation

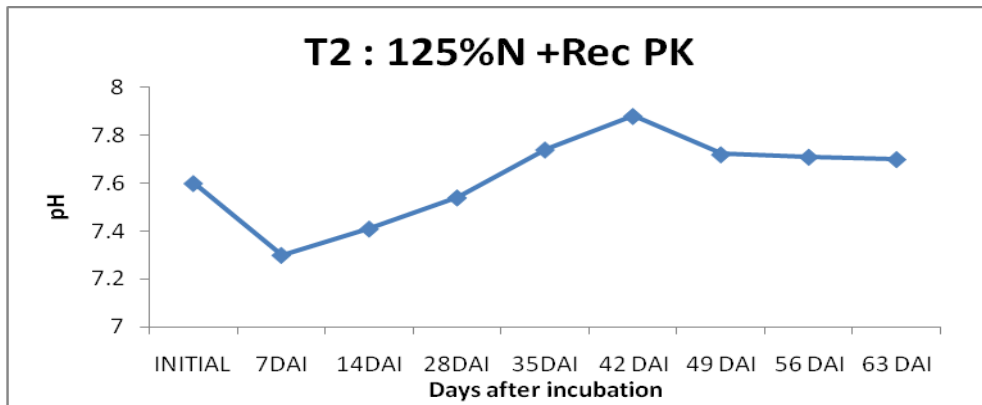


Fig.2b Pattern of change in soil reaction changing pattern by 150 % N + Rec. PK fertilizer during period of incubation

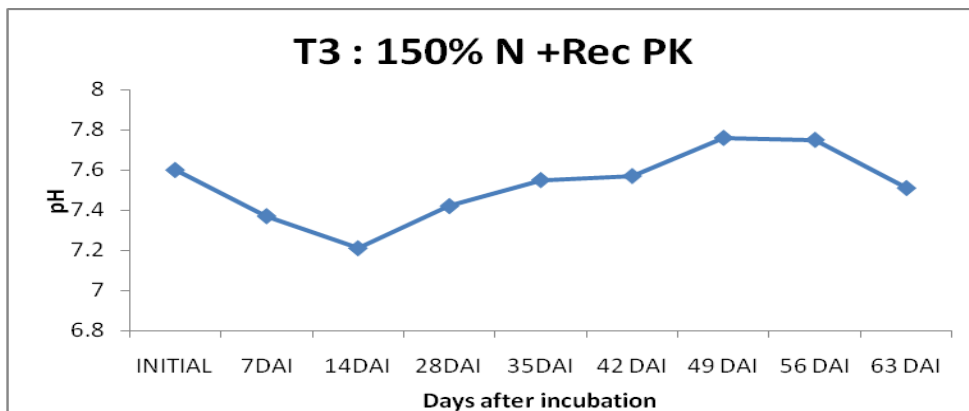


Fig.3a Pattern of change in soil reaction changing pattern by 125 % P + Rec. NK fertilizer during period of incubation

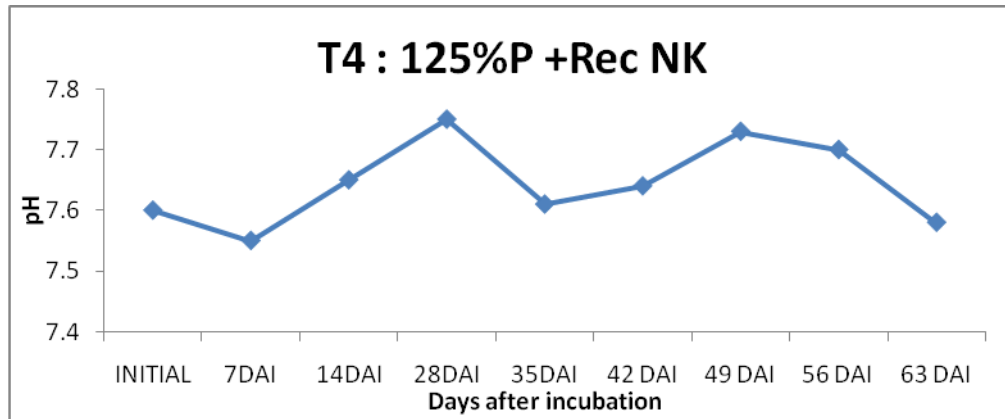


Fig.3b Pattern of change in soil reaction by 150 % P + Rec. NK fertilizer during period of incubation

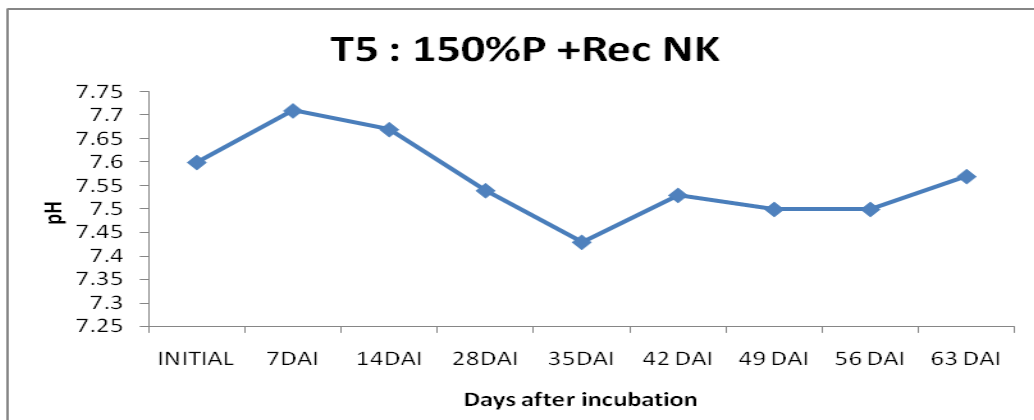


Fig.4a Pattern of change in soil reaction changing pattern by 125 % K + Rec. NP fertilizer during period of incubation

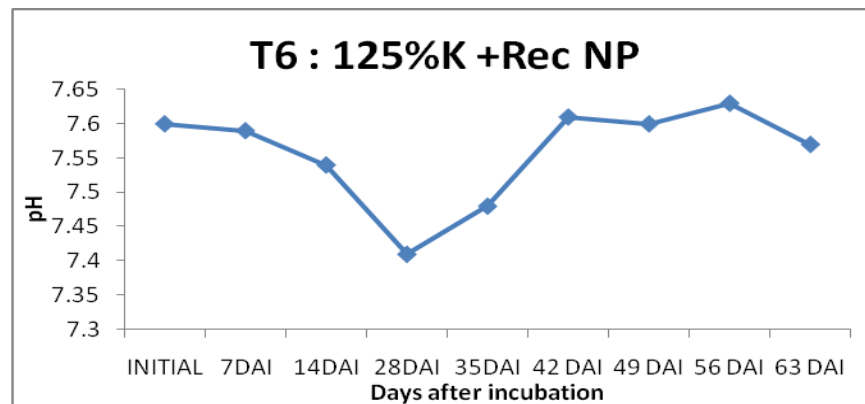


Fig.4b Pattern of change in soil reaction changing pattern by 150 % K + Rec. NP fertilizer during period of incubation

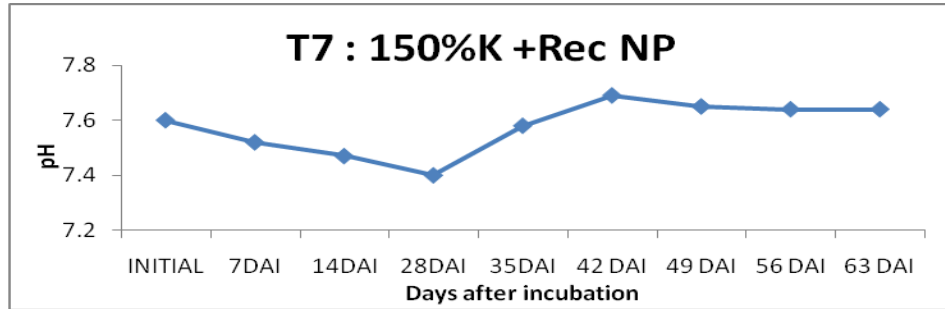


Fig.5a Soil Salinity changing pattern by 125 % N + Rec PK during period of incubation

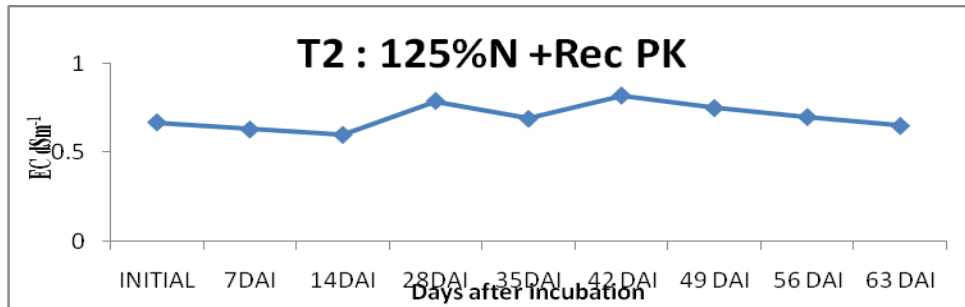


Fig.5b Soil Salinity changing pattern by 150 % N + Rec PK during period of incubation

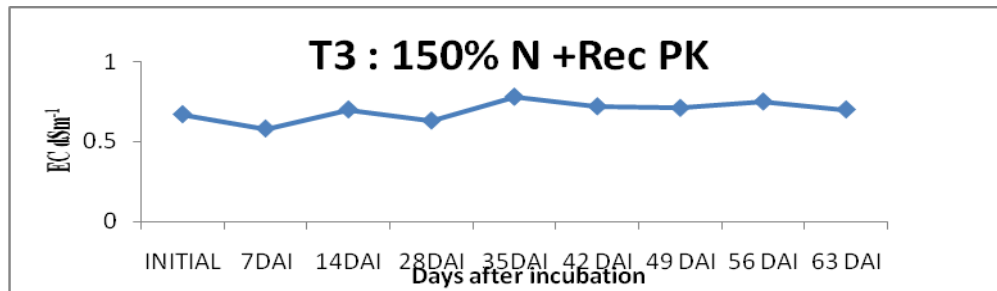


Fig.6a Soil Salinity changing pattern by 125 % P + Rec NK during period of incubation

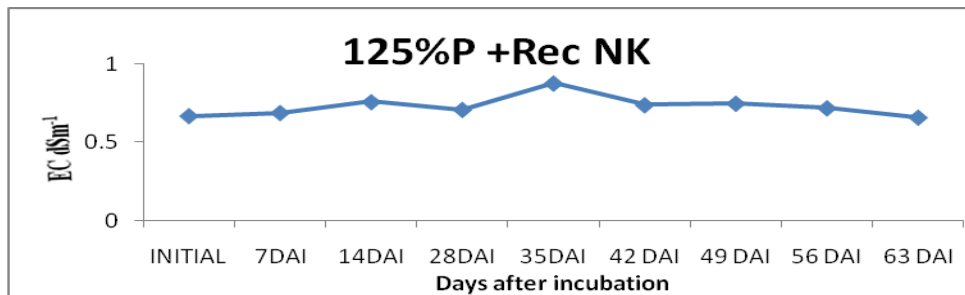


Fig.6b Soil Salinity changing pattern by 150 % P + Rec NK during period of incubation

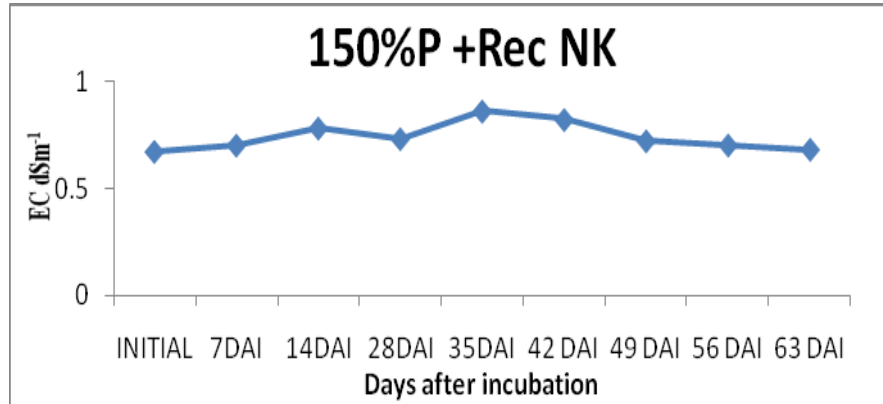


Fig.7a Soil Salinity changing pattern by 125 % K + Rec NP during period of incubation

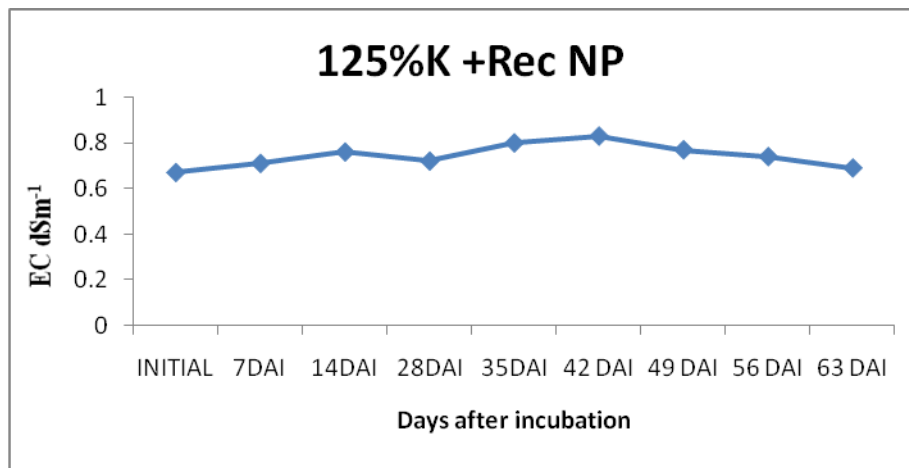
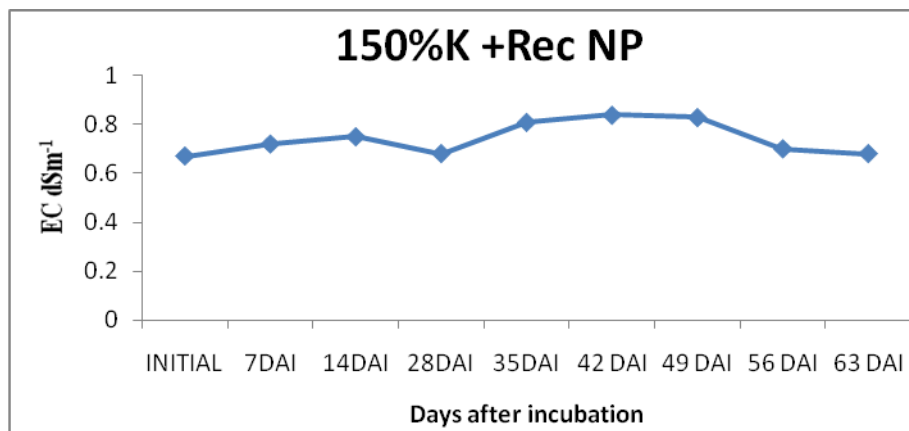


Fig.7b Soil Salinity changing pattern by 150 % K + Rec NP during period of incubation



It is also in agreement with the findings of Meyer *et al.*, (2018), who reported that increase in pH was observed in soil reacted with DAP for 1 hr and lowering of pH values of the soil was noted after 24 hrs. The increase in pH values may be due to the increasing HPO_2^- ion in applied phosphate compounds and with the continuation of the process, more soils came into contact with the fertilizer, leading to the rise in pH of the solution which then became supersaturated with respect to phosphate compounds. The decrease in pH may also be due to the displacement of hydrogen ions from phosphate in solution as a result of precipitation of phosphate ions.

Potassium fertilizers on soil reaction

Generally MOP has no effect on soil acidification. In K treatments, soil got acidified and reached its maximum reduction in the middle of the incubation period. Initial value of pH was 7.6 and the maximum reduction was 7.4 recorded @ 28 DAI in both the 125% and 150% K treated soil (Fig. 4a and 4b). In this study, use of K fertilizers in soil had minimum effect in altering the soil pH. This is also supported by Reis *et al.*, (2018) who observed that potassium fertilizer levels did not affect soil pH. Although decrease in soil pH with the application of fertilizers was expected, it was not seen in this case of study.

If the soil is acidic, the soluble MOP increases the total ionic strength, displaces Al into solution, and so decreases pH. Under normal circumstances showing near neutral pH values, MOP would not alter the pH much. However an acidic soil may show decreased pH values as there are ample amounts of H^+ ions adsorbed that comes into the soil solution as a result of exchange with K. Hence

addition of K can acidify an acidic soil further and no influence over alkaline soils (Roberto *et al.*, 2016)

Effect of NPK fertilizers on soil salinity

Urea on soil salinity

Dissolution of inorganic fertilizers added to soil has several influences on soil physico-chemical properties especially soil salinity. In 100 % NPK treated soil, the salinity level got raised and reached a maximum of 0.88 dS m^{-1} at 35 days after incubation after that it declined in the succeeding weeks. Lopsided pattern of variation in salinity was seen in soil with excess urea. In first two weeks, EC got reduced from 0.67 to 0.60 dS m^{-1} after that the trend altered and utmost salinity of 0.82 dS m^{-1} was reached during 42nd days after incubation in 125 percent N treated soil (Fig. 5a). In 150 per cent N applied soil, complete ups and down level in salinity seen throughout the period (Fig 5b). Comparing both N treatments, maximum unit change in EC was recorded in 125 percent N treated soil. Such N induced salinity levels may affects the nitrification process adversely in soil, which resulted in NO_2 accumulation in the soil (Akhtar and Alam, 2001).

DAP on soil salinity

Increasing tendency in the electrical conductivity was contributed by P fertilizer addition. Soil solution get enriched by soluble salts through the addition of DAP. Among the treatments, highest salinization was noticed in the 125 and 150 % P treated soil. In 125 and 150% DAP treated soil high degree of salinity was recorded *i.e.*, from 0.67 to 0.88 dS m^{-1} and 0.67 to 0.86 dS m^{-1} @ 35 DAI respectively (Fig. 6a and 6b). Changing pattern in salinity during the period was

irregular and reached stability at last week of study. Such salinization pattern was also reported by Naima *et al.*, (2015).

Greater soil salinity caused marked inhibition of the very first step of nitrification during 7 days of incubation, which resulted in lower conversion of NH_4 to $\text{NO}_2\text{-N}$, and consequently a large amount of N was present in NH_4 form at the greatest salinity level (Akhtar *et al.*, 2012). Irshad *et al.*, (2018) also reported that nitrification of NH_4 to NO_3 was reduced by salinity.

MOP on soil salinity

Generally K fertilizers had notable effect over soil reaction and salinity. Application of K @ 125 and 150% recommended dose showed similar pattern in EC of soil throughout the study. The maximum EC of 0.84 dS m^{-1} from initial value (0.67 dS m^{-1}) was observed on 42nd day by the application of 150% recommended K (Fig. 7a). However the highest salinity level was observed during 42 DAI in both the 125 and 150 percent MOP applied soil (Fig. 7a and 7b).

Potassium fertilizer application, usually based on chloride or sulfate salts, could contribute to soil salinization due to their high salt index (Pirhadi *et al.*, 2018). It is also supported by Santos (2013) who observed the increased soil salinity due to higher application of MOP (300 lb/acre).

The present study revealed that the soil reaction and electrical conductivity were influenced by inorganic fertilizer addition. Excess urea application (150% recommended N) showed a prominent acidifying impact on soil. While DAP and MOP application did not impact soil pH considerably as compared to urea. High salinity levels was noticed with

DAP at the rate of 150% P+ Rec NK. Among NPK sources included, MOP had less effect on both soil pH and EC. Hence long term application of excess inorganic fertilizers could undeniably make negative effects to the crop in altering the soil physico chemical properties.

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