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Improved Nutrient Management Practices to Curtail Heavy Nitrogen Use and Enhancing Productivity and Profitability of Wheat Under Indus River Plains of Pakistan-I

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Abstract

A field experiment consisting of integrated nutrients management (INM) and farmer practices (FP) was conducted to find out their effects on wheat crop productivity as well as soil properties. Results show that improving soil fertility by application of all required nutrients in the form of INM practice not only increased soil fertility status particularly soil pH, and macronutrients like NO_3-N, P and K but also enhanced soil organic matter and carbon status. Besides improving soil properties, the INM practice also enhanced crop productivity in comparison to farmer Practice (FP), which was confined to N-based fertilizer only.

Keywords: Balance fertilizer, INM, Productivity, Wheat, Yield

Introduction

In Pakistan nitrogenous (N) chemical fertilizers were introduced in 1952, followed by phosphorus (P) and Potassium (K) in 1959 and 1967 respectively (NFDC, 2014), and these all gained momentum after 1970. Mainly because of growing high-yielding modern wheat and rice varieties by farmers mostly in irrigated areas of the country, and further promoted by the government through subsidies and support price.

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On overall, fertilizer nutrient use increased during this period from almost as low as 1.38 Kg/ha in 1960's to as much as 156 Kg/ha in 2020's and proved to be instrumental in increasing crop yield particularly in staple food like wheat, when yield shoot up from as low as 0.82 t/ha to 2.87 t/ha. With the rapid development of agriculture, the N fertilizer use per unit area of cropland in Pakistan reached 112 Kg/ha in 2019, almost 1.5 times to the world's average (70 Kg/ha) (OurWorldInData.org/fertilizers, FAO), representing 74% of total nutrients offtake followed by P (25%) and K (1.4%) (NFDC, 2020-21) (Figure 1 and Figure 2) so that N:P stands 3.02:1 against the recommended level of 2:1 leading to low N use efficiency (Figure 3) in the country and considered as one of the leading causes of lower wheat productivity (National average yield stands 28 maund/acre).

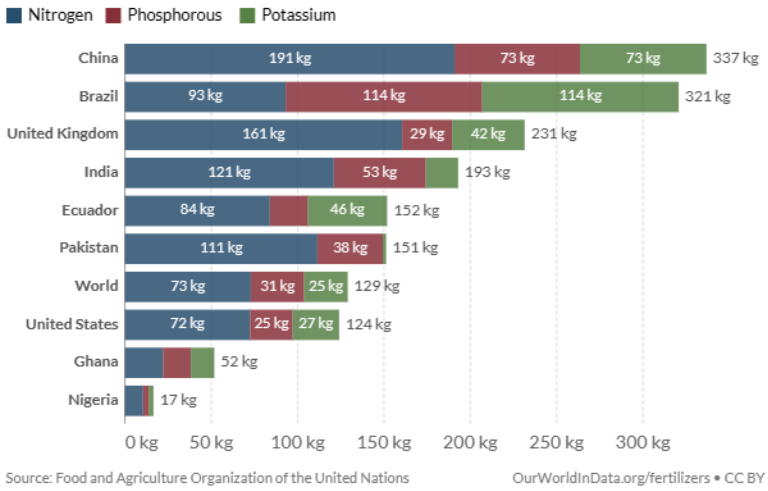

Fig. 1. World Nitrogen, Phosphorus and Potassium based fertilizer Use

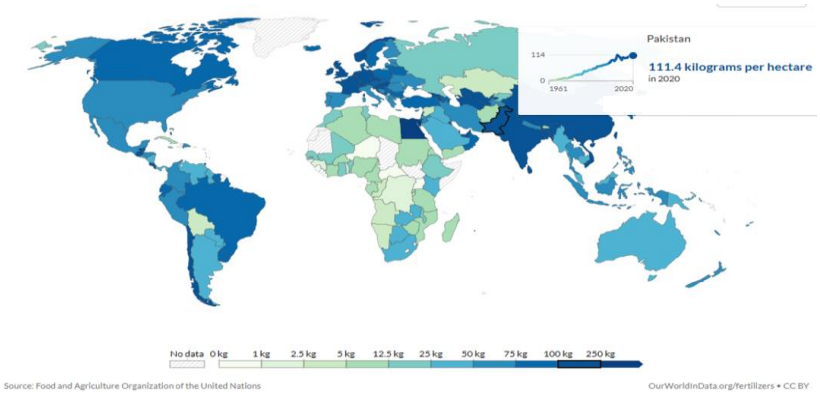

Fig. 2. Relative use of Nitrogen, Phosphorus and Potassium based fertilizer

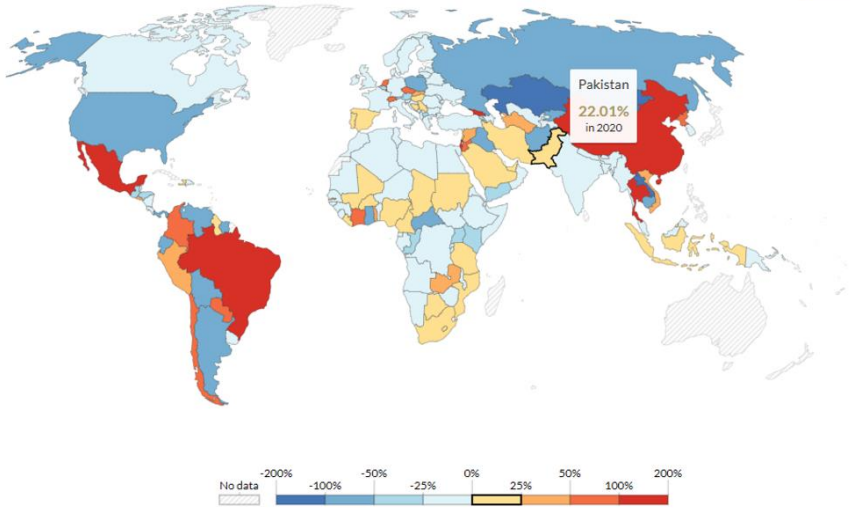

Fig. 3. Low Nitrogen Use Efficiency (NUE)

A growing population coupled with shrinking cultivated land is likely to trigger food insecurity issues soon. Inadequate and imbalanced plant nutrients along with low use of farmyard manure (only 1-5%) (Agri. Stat. 2014-15) leads to land degradation and declined crop productivity in South Asian countries as well as and some other countries (Adhikary et al., 2019; Rakesh et al., 2020; Aryal et al., 2021; Sarkar et al., 2021). Fertilizers such as urea (for N), diammonium phosphate (for N and P), and muriate of potash (for K) provide only primary nutrients, however excessive use of agrochemicals leads to devastating environmental impacts (Dubey et al., 2021).

Integrated nutrient management (INM) is a flexible tactic for the judicious application of inorganic fertilizers and organic manures to maximize the efficiency of production and farmers' profits (Panday et al., 2018; Singh et al., 2017) help achieve sustainable crop production and sustaining soil health (Thakur et al., 2018), and good residual effect on subsequent crops (Parewa et al., 2015; Selim et al. 2020; Khosravi et al., 2018; Sarkar et al., 2021; Tahiri et al., 2022).

Since most agricultural soils in Pakistan are deficient in all three macro-nutrients, and Pakistan stands among the top four in terms of N use but has low mean yields (Figure 1), but with the lowest partial factor productivity (PFP). The N use efficiency (NUE) and highest N surplus and so the potential to increase NUE lies in agronomic practices other than increasing N fertilization, such as balanced crop nutrition, irrigation management, inclusion of legumes in crop rotations, precision in-season N management and the use of enhanced efficiency fertilizers.

The current study aimed at sowing wheat exposed to INM practices where all

macronutrients and micronutrients (Zn, and B) were applied along with organic fertilizer like Biozote and Humic substances in comparison to that grown under Farmer practice (FP) where only Nitrogen was applied. Soil chemical properties, wheat yield and other post-harvest parameters were compared in both practices.

Materials and Methods

A two years field study was conducted across different locations aimed at comparing two fertilizer practices i.e. Farmer practice N @75 Kg/ha) in the form of urea, and integrated nutrient management (INM) NPK @120:90:60 Kg/ha along with micronutrients comprising of all macronutrients such as N, phosphorus, and potassium as urea, DAP and SoP and micronutrients such as Zinc and Boron (Zn 5 Kg/ha, and Boron (as Boric acid) 1 Kg/ha), along with biofertilizer such as Biozote and Humic substances on the productivity of AZRC- Dera a promising wheat variety. Sites were taken as replication namely Lahore, Sialkot, Kotmomin (Sarghoda), and Chawinda (Sialkot-ii) on farmers' field during rabi season. Selected characteristics of soils are given in Table 1. The yield was recorded in quadrate area (1m*1 m). Soil samples were collected from two depths i.e. 0-15 cm (surface soil samples), and 15-30 cm (sub-soil surface) air dried, sieved and analyzed for NO_3-N, P and K using AB-DTPA extraction method (Soultanpour et al., 1985; 1987).

Results and Discussion

Weather data

Mean maximum daily temperature was recorded 26 ºC, while mean minimum daily temperature was recorded 10 ºC during the growing period (Oct-May 2022). Total rainfall was recorded 272 mm (mean 1 mm/day), and average wind speed of 34 Km/hr. (Figure 4.).

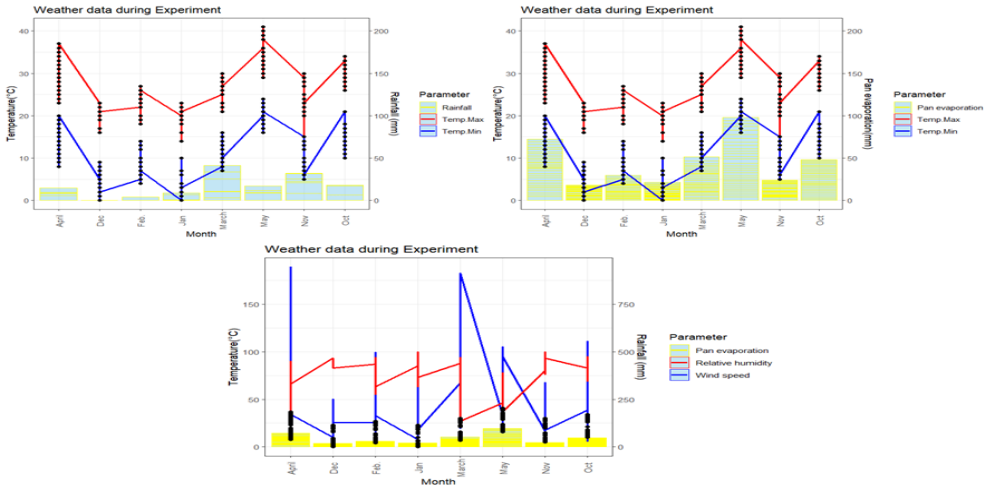

Fig. 4. Mean Weather Conditions during the both crop seasons.

Physicochemical Properties of Soil

Application of balance fertilizer i.e. integrated nutrient management (INM) having all important macro and micronutrients along with organic fertilizers *viz*; Biozote, and Humic substance resulted in decrease of pH of surface soil (0-10 cm) at all sites except Chewinda site vis a vis farmer practice (FP) approach where only nitrogen-based fertilizer has been used.

Change in Soil pH at two Soil Depths

Soil pH is an important soil property influencing nutrients availability and soil health. Among the edaphic factors high soil pH is one of the most dominant soil properties hampering nutrients availability. In the current study it has been observed that soil pH goes on decreasing where plant received all required nutrients such as in case of INM compared to FP (Figure 5). Similar results have been reported elsewhere where soil pH decreased from the initial level of 8.70 to 8.52 with the application of mineral fertilizers in wheat–rice rotations (Yaduvanshi et al., 2003) whereas, just N and little or no P based fertilizer were applied. The decrease in soil pH at upper soil surface may be ascribed to release of organic acid due to decomposition of organic matter in INM vis a vis FP.

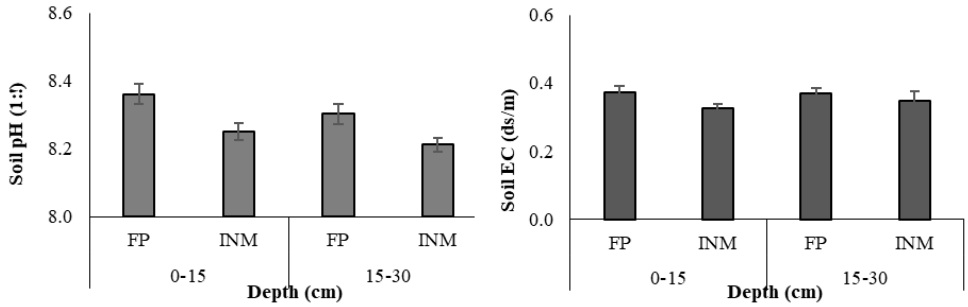

Fig. 5. Response of Soil pH and Electrical Conductivity to FP and INM practices

Soil Nitrate Nitrogen and Phosphorus content

Soil fertility status was evaluated by analyzing soil nitrate nitrogen (NO_3-N), soil phosphorus (P), extractable potassium (K), in soil samples collected from INM plot as well FP plot. Results show statistically significant effect (p<0.01) of fertilizer practices (INM vs. FP) in both years (2021-2022, 2022-2023) and at both soil depths. As evident with application of recommended N, NO_3-N status increased (26%-38%) across both soil depths. However, the increase in soil NO_3-N status of subsurface soil (15-30 cm) was greater (38%) as compared to 26% NO_3-N in surface soil. (Figure 6 A). These findings provide clues to the leaching character of soil with respect to NO_3-N and may be one of the contributing causes of as low as 27% N use efficiency.

Similar trends have been also observed in case of extractable soil P. Results show that statistically significant difference (p<0.01) was found by observing higher soil P in INM practice, 40% more as compared to FP at surface soil (0-15 cm), and relatively higher (44%) soil P was observed at lower soil depth (15-30 cm) in both years (2021-2022, 2022-2023) (Figure 6. B).

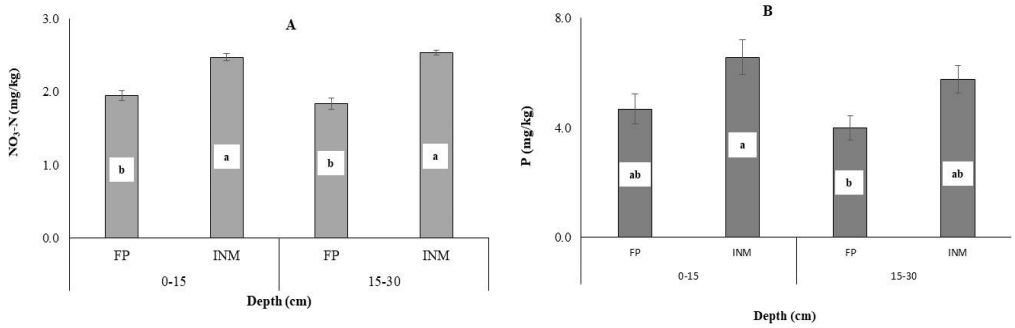

Fig. 6. Response of Soil NO_3-N and Phosphorus to FP and INM practices

Soil Potassium Soil Organic Matter and Organic Carbon Status:

Low soil organic carbon (SOC) of less than 1% is one of the serious issues in most soils in Pakistan. Our results show a 71% and 66% increase in SOM under INM practice over FP at 0-15 and 15-30 cm soil depth respectively (Figure 7). Higher soil pH correlated with higher soil organic matter as deeper soil (15-30 cm). Earlier research also confirmed similar trends (Dhaliwal et al., 2019). The increase in SOC from 37% to 60% when organic fertilizer was applied in conjunction with mineral fertilizer (NPKM) (Jia et al., 2022), similarly, Mercik et al., (1993) reported from a 51 years old experiment that organic carbon in the topsoil layer increased from 3.9 g C kg^{-1} in mineral fertilizer only to 4.8 g C kg^{-1} when manure was added.

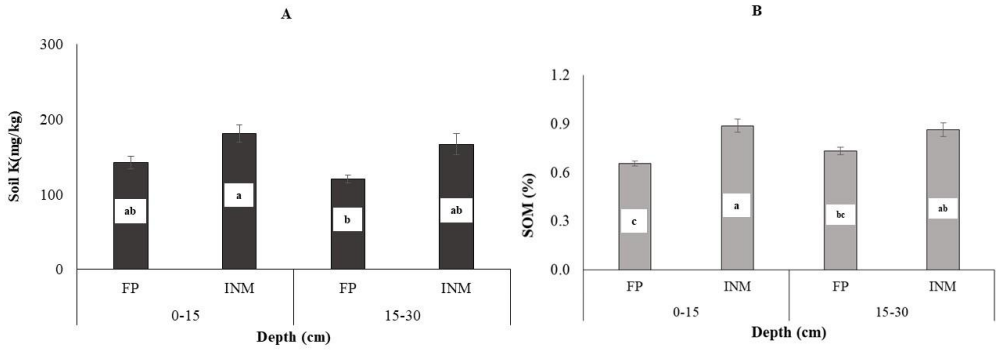

Fig. 7. Response of Soil Potassium and Organic Matter contents to FP and INM practices

Grain yield and Straw: Grain

Increase in grain yield from 14% to 33% has been recorded in INM practice against FP where only nitrogen-based urea fertilizer was applied (Figure 8). Maximum yield was recorded up to 33% as compared to FP at location of Kotmomin. The straw grain ratio ranges from 2.2 in the FP to 1.3 in INM practices, showing that grain yield exceeds straw yield when crop receive integrated nutrients.

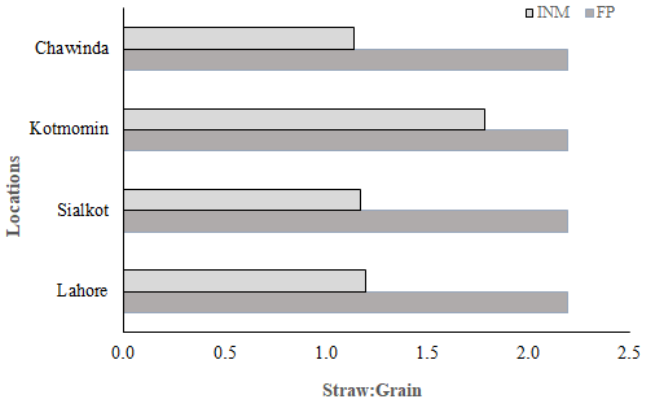

Fig. 8. Straw: Grain under FP and INM practices

Economic Analysis

The economic comparison of return shows that in INM practice total marginal cost (TMC) per acre stands Rs. 18800.00 against total marginal revenue (TMR) of Rs. 32400.00 giving the total of Rs. 13600.00 as net marginal revenue (NMR).

Conclusion

The increase in soil nutrients status has been reflected in the form of increase in crop productivity emphasizing the relation between soil fertility and productivity. The heavy dependence on N fertilizer is neither economically viable nor environmentally feasible. Hence combination of chemical fertilizers along with organic fertilizers stands to be a win–win strategy, which can be helpful in improving the soil fertility as well as wheat productivity.

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