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Soil Quality and Productivity Assessment for Bridging the Rice Yield Gaps in Farmers' Field

Charan Singh[1], Roohi[2*], Amit Kumar[1], Vishal Gandhi[1], Lalita[1], Sukham Madaan[1], Sumit Saini[1], Mahaveer[1], Ashish Jain[1], Rakesh Kumar[1] and Sumit[1]
[1]Assistant Scientist, Rice Research Station, Kaul, Kaithal (Haryana), India.
[2]Assistant Scientist, Regional Research Station, Uchani, Karnal (Haryana), India.

(Corresponding author: Roohi)*
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ABSTRACT: A roving survey of Kaithal and Karnal district of Haryana was conducted during Kharif 2021 to assess the constraints in rice crop production. A total of 24 soil samples from the surveyed sites were collected in triplicate for further analysis. The $pH_{(1:2)}$ and $EC_{(1:2)}$ of the surveyed sites ranged from 7.5 to 9.2 and 0.15 to 0.74 dS/m, respectively. The surveyed soils were non saline in nature. Most of the surveyed sites (around 80%) were found medium in organic carbon status. Available nitrogen ranged from 135-198 kg N/ha, available phosphorus 29.31-53.59 kg P_2O_5/ha and available potassium 223.2-392 kg K_2O/ha in the surveyed sites. The grain yield of rice varieties ranged from 11-99 q/ha whereas the straw yield of rice varieties ranged from 19-119.5 q/ha. The commonly grown rice varieties in scented group were PB 1121, PB 1509 and CSR 30 while the common high yielding non-scented varieties were PR114, PR 126, PR 121. The commonly grown hybrid was 27P-31. Application of sub-optimal doses of herbicides, pesticides and insecticides, raising of nursery in unpuddled fields and rice- wheat sequence were the common practices in all the surveyed districts. The soil related constraints mainly include low organic carbon (some sites) and low nitrogen status of soil, excessive nitrogen fertilizer dose, improper time of nitrogen fertilizer (urea) application and no use of organic source by most farmers.

Keywords: Roving survey, grain yield, straw yield, available nitrogen, nitrogen fertilizer and varietal spectrum.

INTRODUCTION

For over half of the world's population (Pandey *et al.,* 2010), rice (*Oryza sativa* L.) is the primary staple food. The majority of this population resides in less developed nations in Asia, Africa and Latin America. According to current predictions, there will be an additional two billion people on the planet by 2050, bringing the total estimated population to over 9 billion (Godfray *et al.,* 2010). By 2035, rice output must rise by 26% in order to meet the growing demand for the grain and contribute to global food security (Fischer *et al.,* 2014). However, with less land, water and labour available, farmers have been experiencing significant constraints in rice production (Lampayan *et al.,* 2015). In the rice fields of district Kaithal and Karnal, Haryana only one rice crop is generally grown each year from July to November which is followed by wheat. Low soil fertility is widely reported as the major limiting factors for rice productivity in this area. The ability to maintain or improve soil quality is contingent upon our comprehension of the soil's response to agricultural land use (Adita Sambyal *et al.,* 2024). Farmers have a stake in the condition of their soil, so it is not just natural resource managers, lawmakers, and agricultural scientists who are concerned about it. Furthermore, agriculture poses a multitude of environmental risks, such as biodiversity loss, water and land degradation, and climate change (Phalan *et al.,* 2014). It is obvious that increases in food productivity in the agricultural land must be accomplished responsibly given the growing human population and the declining quantity and quality of resources. Accordingly, the Kaithal and Karnal district of Haryana were selected for a roving survey on the recent limitations in rice production related to soil. Closing current "yield gaps" has been recognized as a critical method to fulfill future rice demand (Foley *et al.,* 2011). When comparing mean farm yield to economically sustainable yield through optimal crop management techniques, yield gaps might be a helpful metric (Evans and Fischer 1999). A significant portion of closing production gaps is due to soil-related constraints on output. According to Sumberg (2012), this kind of research can offer a flexible framing plan in policy. A thorough grasp of rice yield gaps and their causes may result in improved strategies to close the yield gap in a sustainable manner (Papademetriou *et al.,* 2000). Haryana, one of the agriculturally important states of India contributes about 7% to the national food grain production with only about 1.33% of geographical area (Shukla *et al.,* 2015). Agriculture predominates in the Kaithal and Karnal district of Haryana, India. Within the district, rice and wheat are the most common crops. Because there isn't much surface water available, aquifer water is mostly used to meet the massive irrigation needs of rice fields. In addition, imbalance application of pesticides and artificial fertilizers such as urea is done to boost output. Assessment of the soil and groundwater quality's appropriateness for sustainable management of these valuable resources is necessary due to the current conditions, which are causing increasing worry about their quality (Goyal *et al.,* 2010). Enhancing the productivity of Kaithal and Karnal's soils is thought to be a practical way to guarantee the state and country's food security because they are among the most significant types of arable soil in North India. Crops produced in most soils experience deficits of one or more micronutrients in addition to primary nutrient deficiencies (Shirin Firoz Khan *et al.,* 2023), despite the fact that the soils frequently have quite adequate overall quantities of the micronutrients (Kumar *et al.,* 2022). Any soil's potential to provide nutrients to crops growing on it is shown by the status of that nutrient. This is the primary factor of external nutrient input when considered in conjunction with crop demand. Considering that only a small portion of all the nutrients in the soil are readily available, understanding the available nutrient status of soils is crucial for planning agricultural fertilization. The practical goal of soil surveys is to facilitate the making of more numerous, accurate, and valuable forecasts for certain objectives like high yield per acre. A robust data bank on soil qualities and related site features is necessary in order to be able to advise current and future land users on how to use the land efficiently for higher and sustainable production. Soil fertility specialists must characterize and analyze fertility and ecological gaps among sites in order to determine the potential yield from each one. According to Abrol *et al.* (2012), a number of variables, including compaction, salinization, erosion, pollution, a drop in organic content, microbial diversity and sealing, affect the health of the soil. In certain regions of India, soil degradation has increased during the last few decades due to a persistent decrease in fertility. According to Mehra *et al.* (2017), this has reduced the soil's capacity to support agricultural productivity. Due to improper fertilizer and chemical application, soil fertility is degrading and the situation has gotten significantly worse in Punjab and Haryana which are the leading Indian states who revolutionized agriculture through the green revolution (Mehra and Singh 2018). This has converted the fertile land into less fertile and degraded land ultimately leading to crop yield stagnation or reduction. However, some farmers are using recommended dose of fertilizers recommended by state agriculture university *i.e.,* CCS Haryana Agricultural university, however some are using indiscriminately which could have negative impact on soil health and fertility. As a result, a roving study was conducted to identify soil related and management constraints limiting the rice productivity at farmers' fields and provide site specific recommendations to the farmers for higher productivity in Kaithal and Karnal, Haryana.

MATERIAL AND METHODS

Kaithal and Karnal are the district of Indian state Haryana and they are situated in the northwest region of the Haryana at about 220 meters above sea level. Kaithal and Karnalhave a total geographic area of 2317 and 2520 square kilometers, respectively. Both districts are a part of Indus-Ganges plains and has a well spread network of western Yamuna canals. Ghaggar and Markanda rivers are significant seasonal waterways in Kaithal district that run in a westerly direction, spanning the Guhla block. The most significant canal that runs through the Pundri, Kaithal, and Kalayat block areas is the Sirsa branch of the Western Yamuna Canal system. The main drainage system in the Karnal is provided by the Yamuna river, which forms the eastern border of the Karnal district. Kaithal district typically receives 511 mm of rain per year whereas Karnal district receives 582 mm of rain per year (Central ground water board, 2015). Mean maximum and minimum temperature of the Kaithal district is 40°C (May & June) and 7°C (January) (Singh *et al.,* 2018). The primary crop for Kharif is paddy, whereas the primary crop for Rabi is wheat in these district. There are two types of soils in the Kaithal district: desert and sierozem soils. The majority of the Kaithal district is covered with sierozem soils, whereas desert soils are found in minor areas, mostly in the north of the district (Central ground water board, 2015). The soils of the southeast Karnal block and Gharaunda are young, stratified and lack profile development. They range from fine sandy loams to sandy. The heavily textured soils in the southeast half of Nilokheri, the eastern part of Nissang, the western half of the Gharaunda block, and the southwest extremity of the Karnal block touching Nilokheri range from sandy loam at the surface to clayey loam at a depth of around one meter (Central ground water board, 2015).

Soil sampling: A total of 72 soil samples from the surveyed sites were collected having three replications of each sample. The samples were then air dried and sieved (2 mm) for laboratory analysis. Portable GPS was used for recording the geographic positions (UTM coordinates) of sites.

Soil pH (1:2) and EC (1:2) was determined in soil using EC and pH meter following procedures underlined in USDA Handbook No. 60 (Richards, 1954). Organic carbon was determined by wet oxidation method (Walkley and Black 1934). Available nitrogen (N) was determined by alkaline permanganate method (Subbaiah and Asija 1956), available phosphorus (P) content was determined by extracting the soil samples using 0.5M $NaHCO_3$ and analyzed by spectrophotometer (Olsen *et al.,* 1954) and available potassium was extracted by using neutral normal ammonium acetate and the content was determined by aspirating the extract into flame photometer (Jackson, 1973).

RESULTS

Area surveyed, varietal spectrum and practices in rice production

Area surveyed: Roving surveys of farmer's field (24 farmers) in 18 villages of 9 blocks were surveyed in the districts of Kaithal and Karnal during June and October, 2021.

Varietal spectrum: The commonly grown rice varieties in scented group were PB 1121, PB 1509, and CSR 30 while the common high yielding non-scented varieties were PR114, PR 126, PR 121. The commonly grown hybrid was 27P-31.

Practices in rice production: In soil, the available nitrogen ranged from 135-198 kg N/ha, available phosphorus 29.31-53.59 kg P_2O_5/ha and available potassium 223.2-392 kg K_2O/ha in the surveyed sites. Low status of nitrogen in soils is the primary reason for low yield at some sites. Nitrogen being a mobile nutrient in soils leach down below root zone and contaminate ground water. This might be a possible reason for low nitrogen status of the soils. Another reason for depletion of soil nitrogen may be nitrogen loss via NH_3 volatilization from soil or floodwater and denitrification. Unbalanced fertilizer with crop intensification exacerbates the deficiency of this important nutrient (Dey and Sekhon 2016). Organic matter increases phosphorus by anion replacement of $H_2PO_4^-$ ion on adsorption sites thereby increasing the quantity of available phosphorus (Sahoo *et al.,* 2020). The soils of these districts are high in potassium content due to alluvial origin and higher micaceous clay content (Patra *et al.,* 2017). The grain yield of scented rice varieties ranged from 11-17 q/ha and of non-scented varieties from 82-99 q/ha. The reason for low grain yield in scented genotypes of the surveyed sites may be crop lodging. The straw yield of scented rice varieties ranged from 19-27 q/ha and of non-scented varieties from 90.5-119.5 q/ha. Around 80% of surveyed sites were found medium (ranging from 0.5%-0.75%) in organic carbon status. The $pH_{(1:2)}$ and $EC_{(1:2)}$of the surveyed sites ranged from 7.5 to 9.2 and 0.15 to 0.74 dS/m, respectively. The surveyed soils were non saline in nature. The probable reason for non saline nature may be low salts in parent material, above average rainfall and good quality irrigation water application due to which salts remains below root zone. Application of sub-optimal doses of herbicides, pesticides and insecticides**,** raising of nursery in unpuddled fields and rice- wheat sequence were the common practices in all the surveyed districts. The variation in grain yield and soil fertility status might be due to major soil and management related constraints at the sites. Those constraints mainly include low organic carbon (some sites) and nitrogen status of soil, high sodicity (Uday Pratap Singh *et al.,* 2023) at some sites, excessive N dose, improper time of N fertilizer (urea) application and no use of organic source by most farmers.

Table 1: Soil survey report of surveyed sites of Kaithal and Karnal district of Haryana during *Kharif*, 2021.

Site No.	Farmers Name	GPS Coordinates (latitude , longitude)	Variety	Grain yield (q/ha)	Straw Yield (q/ha)	$pH_{(1:2)}$	$EC_{(1:2)}$ (dS/m)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Org. Carbon (%)
1.	Sunil	29.74, 76.92	PR114	82	112	9.2	0.22	135	37.10	304.8	0.35
2.	Ramdhiya	29.77, 76.40	CSR 30	13.5	21	8.7	0.57	165	48.09	345.6	0.58
3.	Yogender	29.56, 76.90	PR114	99	119.5	8	0.18	195.2	53.59	253.2	0.6
4.	Jogi ram	29.72, 76.37	CSR 30	16	25.5	8.5	0.42	178	35.72	253.2	0.62
5.	Rinku	29.74, 76.56	CSR 30	13	20	8.4	0.31	186	44.88	352	0.68
6.	Sukhwinder	29.72, 76.37	27P-31	75	90.5	8	0.51	184	50.00	391.2	0.66
7.	Sandeep	29.70, 76.53	CSR 30	14	19	8.5	0.42	198	41.68	369.6	0.54
8.	Kushal Pal	29.72, 76.3	CSR 30	13	21	8.6	0.38	184.2	48.60	380	0.6
9.	Jagbir	29.59, 76.9	PR114	95	114	7.5	0.17	162.8	49.46	223.2	0.58
10.	Rajbir	29.65, 76.92	PR114	98	119	8.2	0.48	192	50.91	368	0.42
11.	Amit Khaira	29.82, 76.68	CSR 30	15	24	8.7	0.32	178.5	37.56	273.6	0.58
12.	Mahender	29.77, 76.60	CSR 30	17	27	7.8	0.27	188	44.88	312	0.53
13.	MahipalSingh	29.72, 76.37	CSR 30	14	22	8.6	0.58	180.5	35.72	346	0.57
14.	Rakesh Kumar	29.76, 76.40	CSR 30	13	21	8	0.71	194	36.50	313.2	0.48
15.	Naresh	29.77, 76.40	CSR 30	14	24	8.1	0.62	183.1	43.97	388.8	0.58
16.	Suresh Kumar	29.77, 76.95	PR114	90	105	8.1	0.22	155	51.10	344	0.52
17.	Sultan singh	29.67, 76.84	PR114	80	96	9.1	0.48	159.4	53.13	300	0.54
18.	Savan Khokhar	29.69, 77.07	PR114	85	107	8.6	0.56	185.4	29.31	252	0.5
19.	Subhash	29.82, 76.85	PR114	85	102	8.2	0.15	180.3	41.20	376	0.38
20.	Suresh Kumar	29.55, 76.97	PR114	80	96.8	8.8	0.57	161	36.18	226.8	0.54
21.	Surender	29.74, 76.42	CSR 30	12.5	26	8.9	0.35	168	49.46	253.2	0.58
22.	Randhir	29.71, 76.32	CSR 30	11	23.5	8.6	0.38	160	52.67	277.2	0.54
23.	Rakesh Kumar	29.77, 76.51	CSR 30	16	21	8.6	0.74	149.5	51.37	272.4	0.48
24.	Rajbir	29.75, 76.38	CSR 30	16	22.5	7.8	0.27	185	51.30	392	0.52
Range				11-99	19-119.5	7.5-9.2	0.15-0.74	135-198	29.31-53.59	223.2-392	0.35-0.68
CV (%)				83.3	74	5.1	41.7	9.2	15.8	17.7	14.6

FUTURE SCOPE

Various recommendation can be made based on this study. The micro scale extensive survey is also recommended for in depth knowledge of soil quality and productivity.

CONCLUSIONS

Based on the observations recorded and intensive interpretation of the results it can be concluded that nitrogen was the most limiting primary nutrient in the surveyed site soils. Low organic carbon (some sites) and low nitrogen status of soil, excessive nitrogen fertilizer dose, improper time of nitrogen fertilizer (urea) application and no use of organic source by most farmers were the major constraints in rice production. However, the famers were advised to apply recommended dose of fertilizers as per CCS Haryana Agricultural University for sustainable crop production. The use of organic manures was also suggested for maintaining organic carbon and soil health.

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Conflict of Interest. None.

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