Current Journal of Applied Science and Technology

27(4): 1-11, 2018; Article no.CJAST.39631
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Long Term Incorporation of Rice Straw along with Inorganic Fertilization to Ameliorate Enzymatic Activities and Soil Properties in Wheat Field

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Authors' contributions

This work was carried out in collaboration between both authors. Author PB conducted the research work, performed the statistical analysis and wrote the first draft of the manuscript. Author SKG managed the analyses of the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2018/39631
Editor(s):
(1) Teresa De Pilli, Assistant Professor, Department of Science of Agriculture of Food of Environment (SAFE), University of Foggia, Via Napoli, Italy.
Reviewers:
(1) Yan Ma, Jiangsu Academy of Agricultural Sciences, China.
(2) Stefan Martyniuk, Instytut Uprawy Nawożenia i Gleboznawstwa Państwowy Instytut Badawczy, Poland.
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(4) Ningappa M. Rolli, BHS Arts & TGP Science College, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/24739

Original Research Article

Received 25th January 2018
Accepted 10th May 2018
Published 24th May 2018

ABSTRACT

Agricultural sustainability is essential for maintaining soil health and long term experiments provide more information about any changes in soil parameters and processes. Soil enzymes and soil physico-chemical properties immediately get altered even with slight change in the soil quality. The research was done to find the impact of long term amendment of different doses of rice straw and inorganic fertilizer at different time intervals in wheat field. It was observed that maximum dehydrogenase activity was observed to be 27.40 µg TPF.hr^{-1}.g^{-1}soil at 45 days after sowing (DAS). Similarly, maximum urease and alkaline phosphatase activity was observed at 45 DAS and recorded to be 330.67 µg urea.hr^{-1}.g^{-1} and 15.882 µg pNP.hr^{-1}.g^{-1}. The treatment having 7.5T RS.ha^{-1} + 120 kg N.ha^{-1} showed higher enzymatic activity as compared to other treatments. The soil physico-chemical properties were also determined and a minor change in soil pH and electrical conductivity was observed. The organic carbon content (0.36%) was altered with increased number of days and higher dose of rice straw. The maximum available nutrients viz. nitrogen in soil was observed to be 136.9 kg.ha^{-1}, phosphorous as 29.94 kg.ha^{-1} and potassium as 120.58 kg.ha^{-1} at

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45 DAS with treatment having 10 $T.ha^{-1}$ rice straw and 150 $kgN.ha^{-1}$. The study revealed that long term experiment exhibited significant improvement with integrated amendment of rice straw and inorganic fertilization in soil enzymatic activities and physico-chemical properties of soil.

Keywords: Alkaline phosphatase, dehydrogenase, inorganic fertilization, urease, rice straw and soil physico-chemical properties.

1. INTRODUCTION

The development in agricultural production emphasizes on wide use of fertilizers to maintain soil fertility and crop yields [1]. Soil fertility and nutrient availability could be enhanced by improving the physical properties and organic matter content of soil through organic fertilization [2]. Rice straw is one of the potential sources of immediate organic substance available in the field itself and has reported to contain 48.7-52.2% C, 0.5-0.8% N, 0.16-0.27% P_2O_5, 1.4-2.0% K_2O, 0.05-0.10% S and 4-7% Si per ton on dry matter basis [3]. Long term studies of the residue recycling over burning have indicated improvements in soil health [4]. Long term utililization of rice straw widens the C:N ratio in the soil, to overcome this problem, additional nitrogen in the form of inorganic fertilizer being used to make up the difference between nitrogen mineralized in the soil and nitrogen required for optimum yields [5-6].

The soaking of the fertilizers into the soil affects the soil enzyme activity levels along with subsequent transformation of nutrients. Soil enzymes have also been suggested as potential markers of soil quality, which could integrate chemical, physical, and biological characteristics to monitor the effects of soil management on long-term productivity [7]. The straw incorporation has significant roles in improving the activity levels of soil enzymes [8]. Soil enzymes, which have been shown to be related to microbial activity, catalyse reactions in soils that are important in nutrient cycling [9]. The concentration of soil nutrients (e.g., organic C, N, P, and K) has their favourable effects on the physico-chemical properties of soil [10-11]. The available form of these nutrients directly absorbed by the plants and thus greatly contributing to the soil quality and hence help in crop development [12].

Wheat is the major part of human diet by contributing 45% of the digestible energy and 30% of total protein and it has also substantial contribution to feeding livestock [13].The huge consumption of this cereal crop by ever increasing population raised its demand for higher production. The higher productivity depends upon soil fertility.

The present research was conducted to analyze the effect of long term integrated application of organic (rice straw incorporation) and inorganic fertilization on various soil enzymes as well as on soil physico-chemical properties.

2. MATERIALS AND METHODS

In a long term experiment, organic and inorganic incorporation has been done since 2005. The field experiment was laid to study enzymatic and soil properties in wheat field (var. PBW621) at Punjab Agricultural University (PAU), Ludhiana, India. Field was laid down in triplicates using standard agronomic practices as mentioned in package and practices of PAU. Rice was the preceding crop for wheat. The different doses of rice straw (0, 5, 7.5 and 10 $T.ha^{-1}$) were incorporated in split plot design every year before the sowing of wheat along with the addition of different N-levels (0, 90,120 and 150 kg $N.ha^{-1}$). Recommended doses of phosphorous (50 kg. ha^{-1}) and potassium (30 $kg.ha^{-1}$) as mentioned in package and practices of PAU were also applied (Except in T1).The recommended dose of fertilizer was applied in three splits within 45 days of crop sowing. Soil samples were collected from 0-15 cm depth from wheat rhizosphere at 0, 45, 90 and 120 DAS in triplicates with the help of auger. The soil samples were analyzed for different soil enzymatic activities (such as alkaline phosphatase, dehydrogenase and urease). Alkaline Phosphatase activity was determined by method of Bessey et al. [14], Dehydrogenase activity was assayed by method of Mersi and Schinner [15] and Urease activity was estimated by Mcgarity and Myers method of McGarity et al. [16]. The soil physico-chemical properties as soil pH [17], soil electrical conductivity [18], soil organic carbon [19], soil available nitrogen [20], available phosphorous [21] and available potassium [22] were determined.

2.1 Treatments

T1	Without Rice Straw	+	Without N Fertilization
T2	5 $T.ha^{-1}$ Rice Straw	+	Without N Fertilization
T3	7.5 $T.ha^{-1}$ Rice Straw	+	Without N Fertilization
T4	10 $T.ha^{-1}$ Rice Straw	+	Without N Fertilization
T5	Without Rice Straw	+	90 kg $N.ha^{-1}$
T6	5 $T.ha^{-1}$ Rice Straw	+	90 kg $N.ha^{-1}$
T7	7.5 $T.ha^{-1}$ Rice Straw	+	90 kg $N.ha^{-1}$
T8	10 $T.ha^{-1}$ Rice Straw	+	90 kg $N.ha^{-1}$
T9	Without Rice Straw	+	120 k $N.ha^{-1}$
T10	5 $T.ha^{-1}$ Rice Straw	+	120 kg $N.ha^{-1}$
T11	7.5 $T.ha^{-1}$ Rice Straw	+	120 kg $N.ha^{-1}$
T12	10 $T.ha^{-1}$ Rice Straw	+	120 kg $N.ha^{-1}$
T13	Without Rice Straw	+	150 kg $N.ha^{-1}$
T14	5 $T.ha^{-1}$ Rice Straw	+	150 kg $N.ha^{-1}$
T15	7.5 $T.ha^{-1}$ Rice Straw	+	150 kg $N.ha^{-1}$
T16	10 $T.ha^{-1}$ Rice Straw	+	150 kg $N.ha^{-1}$

2.2 Statistical Analysis

Microsoft Excel 97-2003 was used in the statistical processing of the data. The enzymatic activity and soil physico-chemical properties were analyzed with DSTAAT.

3. RESULTS AND DISCUSSION

Long term integrated application of rice straw and inorganic fertilization revealed following observations in concern with soil enzymatic activities and soil physico-chemical properties.

3.1 Soil Enzymes

The study was done to analyze the effect of long term incorporation of rice straw and inorganic nitrogen fertilization on different soil enzymes viz. dehydrogenase, urease and alkaline phosphatase at different time intervals (0, 45, 90 & 120 DAS) from wheat rhizospheric soil samples. It was exhibited that there was significant increase in the enzymatic activity with crop development when compared to zero day enzymatic activity. The intracellular dehydrogenase enzyme found to be maximum at 45 DAS with 7.5 $T.ha^{-1}$ rice straw along with 120 kg $N.ha^{-1}$ i.e, T11 (27.40 µg $TPF.hr^{-1}.g^{-1}$ soil) followed by T16 (24.90 µg $TPF.hr^{-1}.g^{-1}$ soil) and T15 (22.80 µg $TPF.hr^{-1}.g^{-1}$ soil). The results showed that there was decrease in dehydrogenase activity at 90 DAS and 120 DAS as compared to 45 DAS, it might be due to decrease in atmospheric temperature during winter season (Table 1). The average atmospheric temperature at 90 DAS and 120 DAS were observed to be 10ºC and 14ºC respectively. Similarly the activity of urease enzyme found to be maximum at 45 DAS with T11 (330.67 µg $urea.hr^{-1}.g^{-1}$ soil) followed by T16 (329.85 µg $urea.hr^{-1}.g^{-1}$ soil) and T15 (328.78 µg $urea.hr^{-1}.g^{-1}$ soil). The results of alkaline phosphatase enzymes also observed to be maximum with T11 (15.882 µg $pNP.hr^{-1}.g^{-1}$ soil) followed by T16 (15.558 µg $pNP.hr^{-1}.g^{-1}$ soil) and T15 (15.438 µg $pNP.hr^{-1}.g^{-1}$ soil) at 45 DAS. The urease and alkaline phosphatase activities were found to be lower at 90 and 120 DAS when compared to the activities at 45 DAS (Tables 2 & 3). The observation showed that the enzymatic activity of different enzymes was significantly higher with treatment T11 having 7.5 $T.ha^{-1}$ rice straw along with 120 $kgN.ha^{-1}$ followed by T16 (10 $T.ha^{-1}$ RS + 150 kg $N.ha^{-1}$) and T15 (10 T. ha^{-1} RS + 150 kg $N.ha^{-1}$).

Soil enzymes, which reflects the soil health are related to microbial biomass and activity, catalyse reactions in soils that are important in nutrient cycling [9]. Garg and Bahl [8] also reported that straw incorporation has significant roles in improving the activity levels of soil enzymes and microbial biomass communities. According to Bandick and Dick [23] residue incorporation in the soil can increase the activity levels of various soil enzymes and these enzymatic activities are usually higher with organic fertilization when compared to chemical fertilizers alone [24]. The dehydrogenase, urease and phosphatase activities were found to be higher with rice straw treated soil samples and a

Table 1. Effect of incorporation of different doses of rice straw and N fertilizer on soil dehydrogenase enzymatic activity in wheat crop at different time intervals

Treatments	Dehydrogenase (µg TPF.hr^{-1}.g^{-1}soil)			
	0 DAS	**45 DAS**	**90 DAS**	**120 DAS**
T1	0.30**n**	1.03**o**	0.78**p**	0.57**n**
T2	0.88**m**	1.94**n**	1.45**o**	1.06**m**
T3	1.27**k**	2.97**m**	2.21**n**	2.04**i**
T4	1.06**l**	3.49**l**	2.76**m**	2.10**hi**
T5	1.09**l**	6.47**k**	3.00**l**	1.24**l**
T6	1.33**j**	7.48**j**	3.43**k**	1.45**k**
T7	1.97**g**	12.16**h**	7.75**h**	2.61**g**
T8	2.27**f**	13.92**g**	8.48**g**	3.10**e**
T9	1.39**i**	7.84**j**	3.80**j**	1.91**j**
T10	2.79**d**	17.82**e**	10.58**e**	3.16**e**
T11	3.22**a**	27.40**a**	15.87**a**	5.68b
T12	2.94**c**	20.71**d**	11.89**d**	4.10**d**
T13	1.48**h**	8.60**i**	4.22**i**	2.15**h**
T14	2.52**e**	16.81**f**	9.15**f**	2.82**f**
T15	2.91**c**	22.80**c**	14.05**c**	4.46**c**
T16	3.07**b**	24.90**b**	15.32**b**	4.98**b**

Values represent mean of three replications.
Same letter within each column indicate no significant differences among the treatments (P≤0.05)

Table 2. Effect of incorporation of different doses of rice straw and N fertilizer on soil urease enzymatic activity in wheat crop at different time intervals

Treatments	Urease (µg urea.hr^{-1}.g^{-1}soil)			
	0 DAS	**45 DAS**	**90 DAS**	**120 DAS**
T1	145.61**n**	202.78**o**	199.70**p**	162.23**p**
T2	156.68**m**	231.50**n**	203.96**o**	163.77**o**
T3	161.88**k**	256.32**l**	208.81**n**	166.02**m**
T4	160.34**l**	254.43**m**	213.06**m**	164.95**n**
T5	164.95**j**	283.39**k**	216.96**l**	180.56**l**
T6	177.01**i**	288.12**j**	233.04**k**	182.09**k**
T7	181.03**g**	311.64**g**	254.67**h**	187.53**h**
T8	185.52**f**	323.82**f**	256.80**g**	189.30**g**
T9	179.14**h**	296.87**i**	247.22**j**	184.10**j**
T10	190.01**d**	327.36**d**	270.27**e**	195.57**e**
T11	266.61**a**	330.67**a**	304.91**a**	212.23**a**
T12	191.67**c**	328.07**cd**	283.39**d**	198.76**d**
T13	180.20**g**	299.94**h**	251.60**i**	185.76**i**
T14	187.65**e**	324.88**e**	263.77**f**	193.56**f**
T15	192.14**c**	328.78**c**	296.16**c**	199.82**c**
T16	193.32**b**	329.85**b**	303.61**b**	201.48**b**

Values represent mean of three replications.
Same letter within each column indicate no significant differences among the treatments (P≤0.05)

decline in soil enzymatic activities towards crop maturity was observed. Present results were similar with the findings of Gaind and Nain [25] who reported that the decrease may be associated to low microbial count related to poor availability of substrate to sustain microbial biomass. Low enzymatic activity in soil during winter compared to warmer season was also reported by Ross et al. [26].

3.2 Soil Physico-chemical Properties

The wheat rhizospheric soil was analyzed to observe various soil properties viz. soil pH, soil EC, soil OC content and soil available nutrients (N, P & K) at different time intervals (0, 45, 90 & 120 DAS) of crop development. In this long termed experiment the soil pH was observed to be altered from 7.81 to 6.99 (Figs. 1a, b, c & d).

Table 3. Effect of incorporation of different doses of rice straw and N fertilizer on soil alkaline phosphatase enzymatic activity in wheat crop at different time intervals

Treatments	Alkaline Phosphatase (µg PNP.hr^{-1}.g^{-1} soil)			
	0 DAS	**45 DAS**	**90 DAS**	**120 DAS**
T1	7.602**l**	11.460**j**	11.423**p**	8.416**o**
T2	7.843**k**	11.969**i**	11.571**o**	9.101**n**
T3	8.611**i**	13.171**h**	12.773**l**	9.980**k**
T4	8.194**j**	12.015**i**	11.645**n**	9.896**l**
T5	8.657**i**	13.199**h**	13.134**k**	9.332**m**
T6	8.675**i**	13.523**g**	13.347**j**	9.970**k**
T7	8.981**h**	14.984**d**	14.170**h**	10.840**i**
T8	9.240**g**	15.151**c**	14.216**g**	11.228**g**
T9	8.888**h**	13.791**f**	12.450**m**	10.285**j**
T10	10.729**d**	15.262**c**	14.457**e**	11.645**e**
T11	12.450**a**	15.882**a**	15.641**a**	13.939**a**
T12	10.405**e**	14.984**d**	14.864**d**	12.339**d**
T13	8.971**h**	14.161**e**	13.458**i**	11.025**h**
T14	9.526**f**	15.206**c**	14.355**f**	11.506**f**
T15	12.015**c**	15.438**b**	15.031**c**	13.671**c**
T16	12.311**b**	15.558**b**	15.160**b**	13.846**b**

Values represent mean of three replications.
Same letter within each column indicate no significant differences among the treatments ($P \leq 0.05$)

Decline in pH might have resulted from build-up of organic matter with time in fertilizer plots. The similar decrease in soil pH with long term integrated application of organic and inorganic fertilizers was also observed by Brar et al. [27] and Benbi and Brar [28]. The pH was significantly reduced to 6.99 with 10 t RS.ha^{-1} and 150 kg N.ha^{-1} at 120 DAS. There was no significant decrease in soil pH till 90 DAS of crop development. Decline in soil pH can have positive impacts on availability of nutrients such as phosphorus, zinc, iron and manganese [28]. The availability of phosphorus is more in the pH range from 6.5 to 7.5. Use of urea fertilizer and build-up of organic matter might have resulted in decrease in pH [28] as high nitrogen rate lowers the pH of the soil. The soil EC showed alteration from 0.218 to 0.201dSm^{-1} in this long termed experiment. The change was observed to be non-significant (Fig. 2a, b, c & d). The researchers, Brar et al. [27] also reported non significant observations for EC in their 36 years long term experiment. The EC values in all treatments were less than 0.8 dS m^{-1}, which is considered safe for growth of all crops. The change in pH and EC was not a considerable change although the change was there parenthetically with different doses of rice straw and different nitrogen levels.

The organic carbon content was ranged from 0.26% to 0.36% for different fertilizer treatments. The organic carbon content was found to be maximum (0.36%) at crop maturity (120 DAS) with T11 followed by T16 (0.35%) and by T12 (0.34%). This increase in organic carbon content might be due to addition of rice straw that acts as rich source of carbon that goes back into the soil. The change in organic carbon content was found to be significant (Fig 3a, b, c & d) at different time intervals when compared to zero DAS. Similarly, increase in organic carbon content of soil was observed when treated with integrated application of organic and inorganic fertilizer in long term experiments [29-31]. The soil organic matter levels and soil microbial activities are vital for nutrient turnover and according to report of Goyal et al. [32] long term productivity of soil were enhanced by use of organic amendments along with inorganic fertilizers.

The soil available nutrients viz. nitrogen, phosphorous and potassium were studied from wheat rhizospheric soil samples. The available nitrogen was found to be maximum at 45 DAS with T16 (136.9 kg.ha^{-1}) followed by T15 (134.9 kg.ha^{-1}) and T12 (133.3 kg.ha^{-1}). The available phosphorous was observed to be maximum at 45 DAS with T16 (29.94 kg.ha^{-1}) followed by T15 (29.88 kg.ha^{-1}) and T14 (29.87 kg.ha^{-1}). The available potassium found to be maximum at 45 DAS with T11 (120.58 kg.ha^{-1}) followed by T16 (119.86 kg.ha^{-1}) and T12 (119.32 kg.ha^{-1}). The available nutrients observed to be decreased with crop maturity. It was observed that the various available plant nutrients studied i.e,

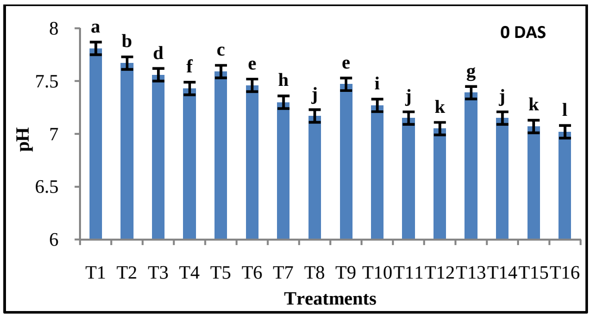

Fig. 1a. Effect of incorporation of different doses of rice straw and N fertilizer on soil pH in wheat crop at 0 DAS

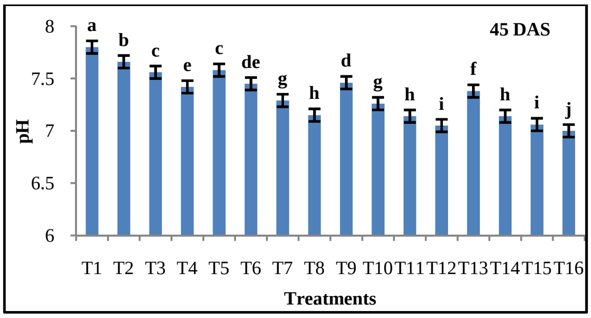

Fig. 1b. Effect of incorporation of different doses of rice straw and N fertilizer on soil pH in wheat crop at 45 DAS

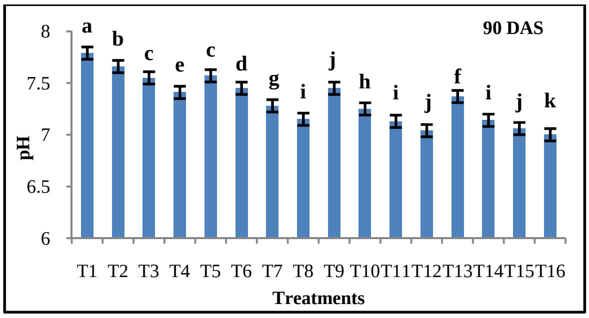

Fig. 1c. Effect of incorporation of different doses of rice straw and N fertilizer on soil pH in wheat crop at 90 DAS

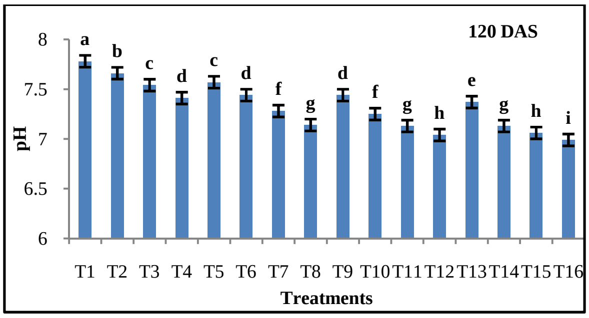

Fig. 1d. Effect of incorporation of different doses of rice straw and N fertilizer on soil pH in wheat crop at 120 DAS

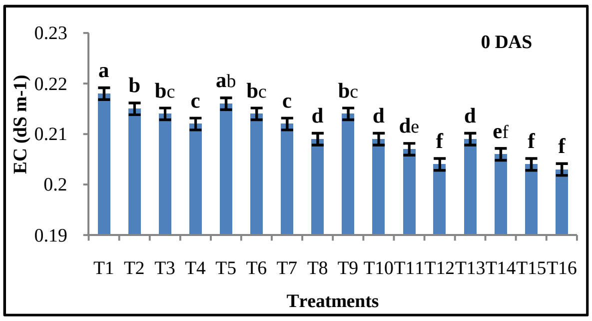

Fig. 2a. Effect of incorporation of different doses of rice straw and N fertilizer on soil EC in wheat crop at 0 DAS

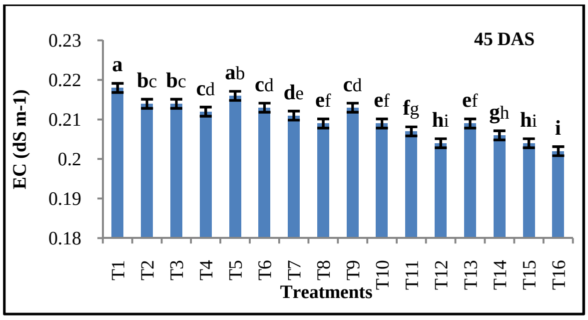

Fig. 2b. Effect of incorporation of different doses of rice straw and N fertilizer on soil EC in wheat crop at 45 DAS

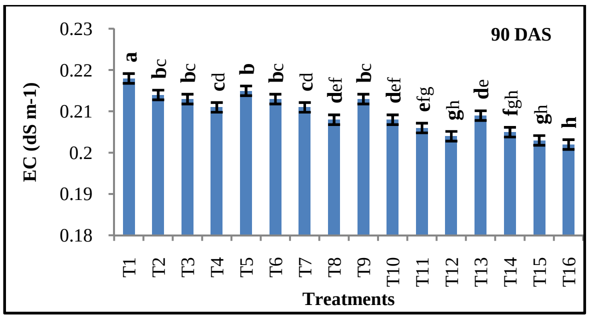

Fig. 2c. Effect of incorporation of different doses of rice straw and N fertilizer on soil EC in wheat crop at 90 DAS

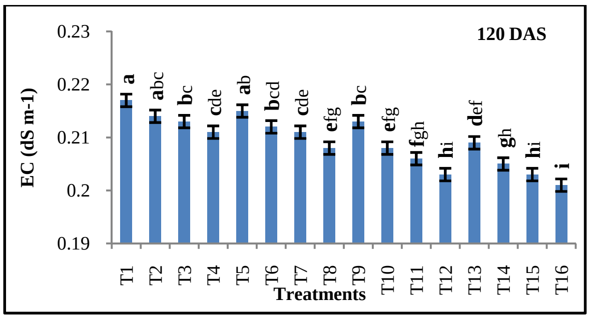

Fig. 2d. Effect of incorporation of different doses of rice straw and N fertilizer on soil EC in wheat crop at 120 DAS

The incorporation of crop residue into the soil and its subsequent decomposition replenishes the soil organic matter content and also supplies essential nutrients after mineralization [33]. It was also reported that the use of organic and inorganic fertilizers in balanced and integrated form enhance the accumulation of soil organic matter and improves soil physical properties [27]. Similar to the results of the present study, Pathak et al. [34] found that both the nutrient contents and their availability increased after the incorporation of crop residues in the plowing layer in the field experiment at Indian Agricultural Research Institute. The present results were agreed with the findings of a five year straw incorporation experiments by Zhou et al. [35] who reported that N, P and K contents increased substantially in the 0-20 cm soil layer. Liu et al. [36] also observed that long-term straw retention and the application of chemical fertilizers could increase the available P and available K concentrations in the top soil layer. Similarly, Garg and Bahl [8] who indicated that combined use of crop residues and chemical fertilizers resulted in significantly higher available nutrients.

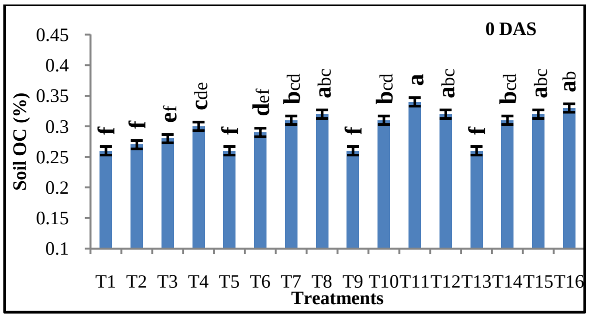

Fig. 3a. Effect of incorporation of different doses of rice straw and N fertilizer on soil OC content in wheat crop at 0 DAS

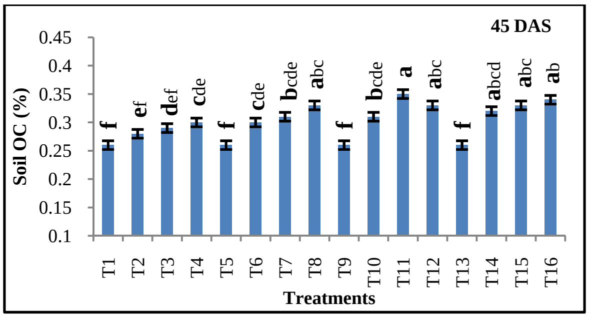

Fig. 3b. Effect of incorporation of different doses of rice straw and N fertilizer on soil OC content in wheat crop at 45 DAS

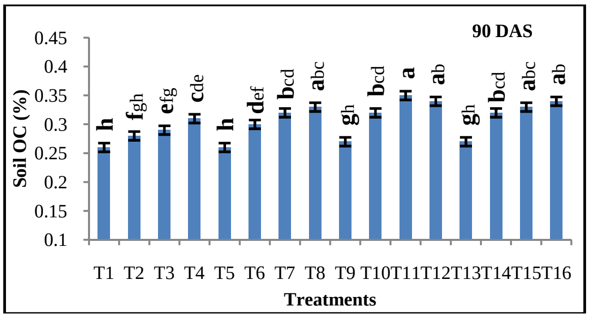

Fig. 3c. Effect of incorporation of different doses of rice straw and N fertilizer on soil OC content in wheat crop at 90 DAS

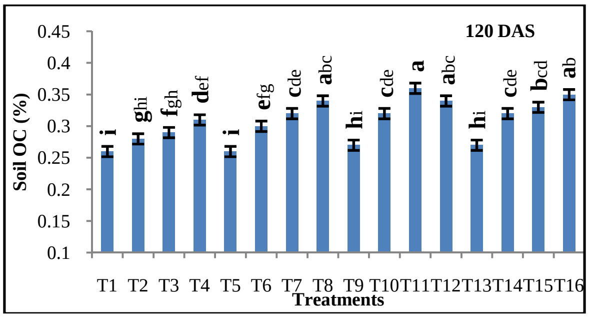

Fig. 3d. Effect of incorporation of different doses of rice straw and N fertilizer on soil OC content in wheat crop at 120 DAS

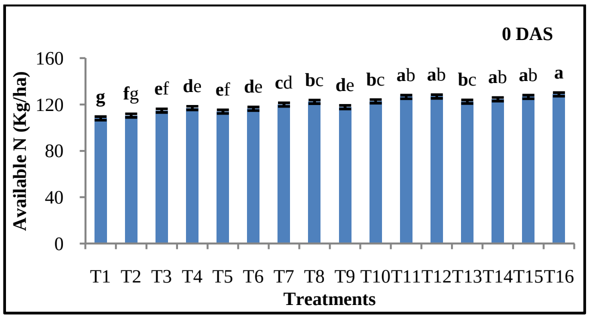

Fig. 4a. Effect of incorporation of different doses of rice straw and N fertilizer on soil available N in wheat crop at 0 DAS

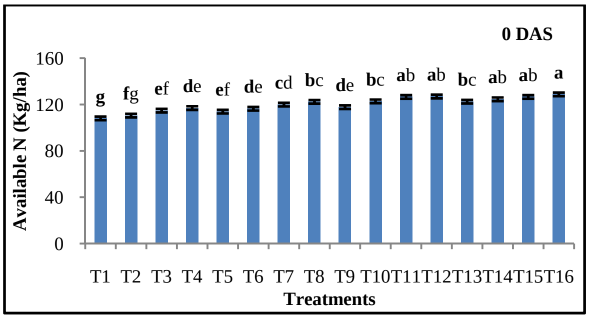

Fig. 4b. Effect of incorporation of different doses of rice straw and N fertilizer on soil available N in wheat crop at 45 DAS.

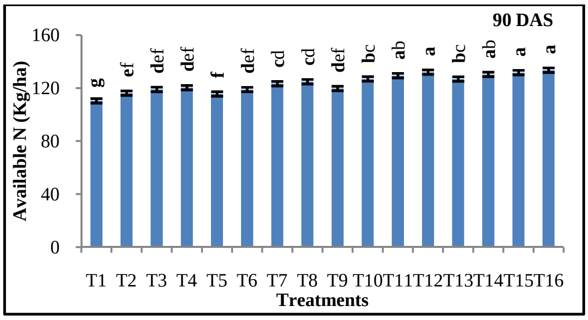

Fig. 4c. Effect of incorporation of different doses of rice straw and N fertilizer on soil available N in wheat crop at 120 DAS

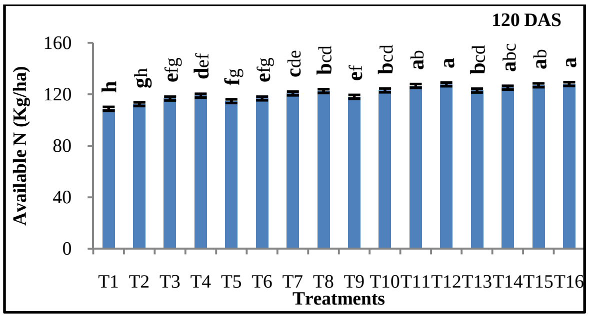

Fig. 4d. Effect of incorporation of different doses of rice straw and N fertilizer on soil available N in wheat crop at 90 DAS

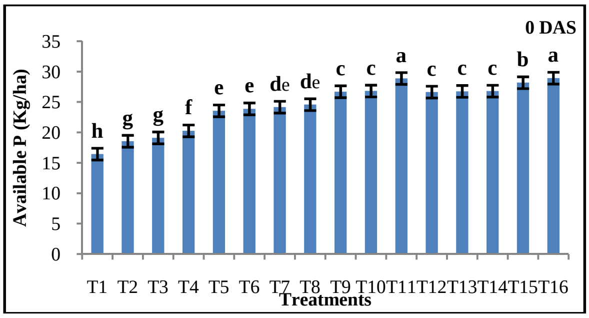

Fig. 5a. Effect of incorporation of different doses of rice straw and N fertilizer on soil available P in wheat crop at 0 DAS

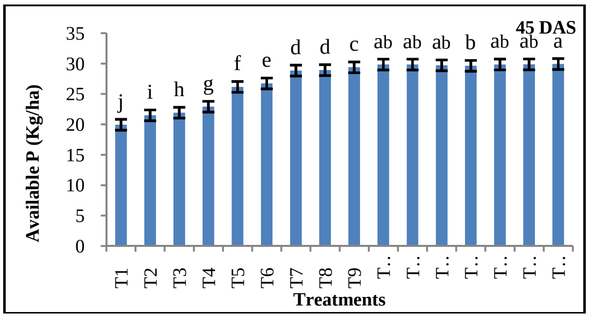

Fig. 5b. Effect of incorporation of different doses of rice straw and N fertilizer on soil available P in wheat crop at 45 DAS.

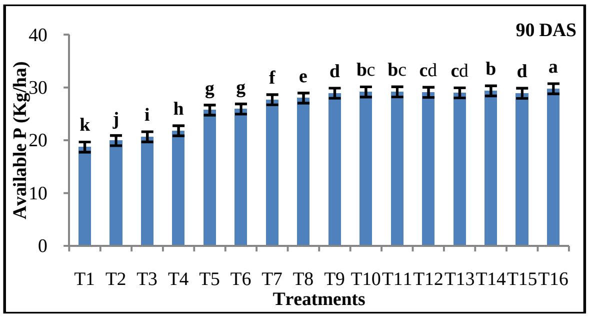

Fig. 5c. Effect of incorporation of different doses of rice straw andN fertilizer on soil available P in wheat crop at 90 DAS

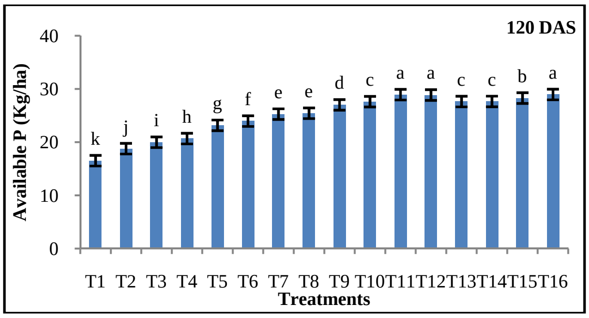

Fig. 5c. Effect of incorporation of different doses of rice straw and N fertilizer on soil available P in wheat crop at 90 DAS

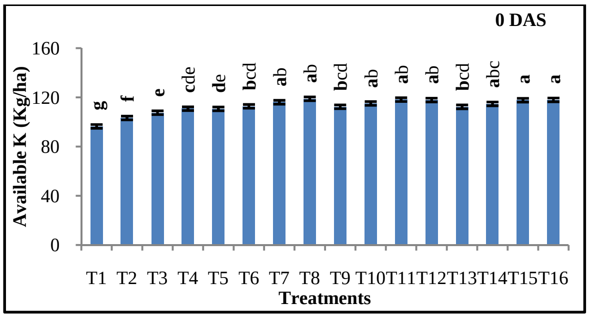

Fig. 6a. Effect of incorporation of different doses of rice straw andN fertilizer on soil available K in wheat crop at 0 DAS

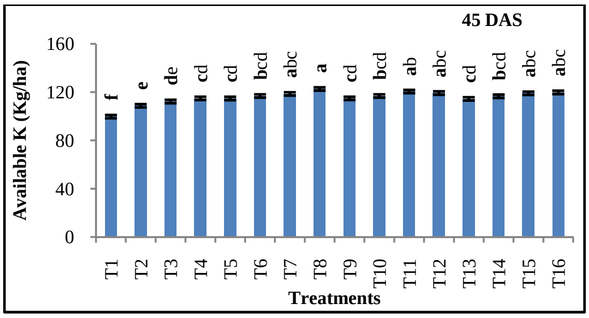

Fig. 6a. Effect of incorporation of different doses of rice straw and N fertilizer on soil available K in wheat crop at 0 DAS

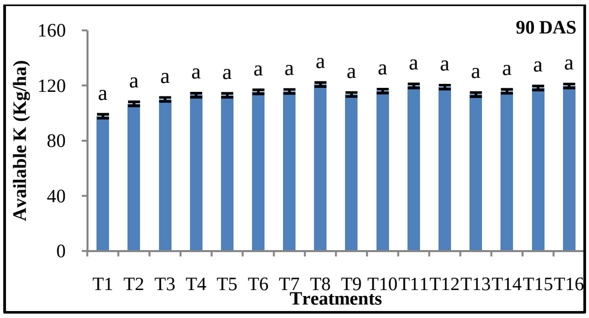

Fig. 6c. Effect of incorporation of different doses of rice straw and N fertilizer on soil available K in wheat crop at 90 DAS

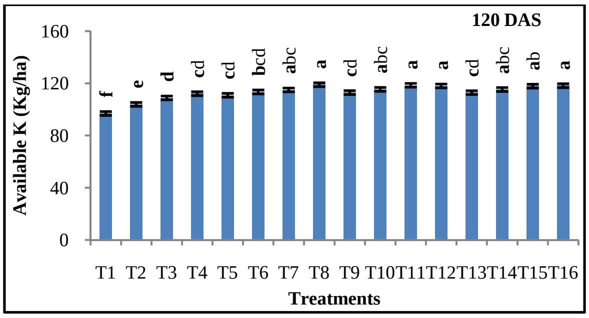

Fig. 6d. Effect of incorporation of different doses of rice straw and N fertilizer on soil available K in wheat crop at 120DAS

4. CONCLUSION

The application of organic and inorganic treatment in different doses in wheat field resulted in improved rhizospheric microbial activities that ameliorate different soil enzymes which subsequently enhanced soil physico-chemical properties. The application of 7.5T RS.ha^{-1} along with 120 kg N/ha showed maximum enzymatic activity while 10T RS.ha^{-1} along with 150 kg N.ha^{-1} showed maximum physico-chemical properties of soil although the results were statistically at par with 7.5T RS.ha^{-1} along with 120 kg N.ha^{-1}. The present study concluded that enzymatic activities and physico-chemical properties of soil were observed to be statistically higher with 7.5 T.ha^{-1} and 10 T.ha^{-1} rice straw along with the application of 120 kg N.ha^{-1} and 150 kg N.ha^{-1} inorganic fertilizer in comparison to control and 5 T.ha^{-1} rice straw and control and kg N.ha^{-1} inorganic fertilizer. The rice straw at the rate 7.5 T.ha^{-1} and 10 T.ha^{-1} and inorganic fertilizer at the rate 120 kg N.ha^{-1} and 150 kg N.ha^{-1} were found to be statistically at par.

ACKNOWLEGEDEMENT

The research work was supported by Punjab Agricultural University, Ludhiana, Punjab, 141003, India.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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