International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(6): 2942-2947

Received: 13-09-2019
Accepted: 17-10-2019

Khaidem Jackson
School of Agriculture, Lovely Professional University, Punjab, India

Nitin M Changade
School of Agriculture, Lovely Professional University, Punjab, India

Premasis Sukul
School of Agriculture, Lovely Professional University, Punjab, India

Thounaojam Thomas Meetei
School of Agriculture, Lovely Professional University, Punjab, India

Yumnam Bijilaxmi
School of Agriculture, Lovely Professional University, Punjab, India

Corresponding Author:
Nitin M Changade
School of Agriculture, Lovely Professional University, Punjab, India

Efficacy of organic and inorganic fertilizer on soil properties, growth and yield attributes of wheat crop

Khaidem Jackson, Nitin M Changade, Premasis Sukul, Thounaojam Thomas Meetei and Yumnam Bijilaxmi

Abstract
The application of different fertilizer dosage may impact the soil physical and chemical properties along with the efficiency of the plants. A field experiment was conducted during the *Rabi* season of 2018-19 at the research farm of Lovely Professional University, Phagwara (Punjab). Experiment was conducted in order to determine the best combination of organic and inorganic fertilizers for improvement of plant growth and yield parameters as well as improvement of soil physico-chemical properties. The seven treatments were incorporated, i.e., control (T0), T1 (100% Recommended dose of fertilizer), T2 (75% RDF+PSB), T3 (50% RDF), T4 (5 tha^{-1} vermicompost), T5 (75% RDF+5 tha^{-1} vermicompost) and T6 (50% RDF+2.5 tha^{-1} vermicompost). Treatment T1 was observed with 104.33 cm plant height and T5 with 93.50 cm. The grain number per spike of the treatments were calculated at peak values of 45.44, 44.89 and 43.66 in treatments T6, T2 and T5 respectively. Organic carbon percentage, available P were obtained at 0.53% and 16.21 $kgha^{-1}$ respectively in mixed organic and inorganic treatment T5. Results showed that treatment T5 showed promising results based on both plant parameters and soil physico-chemical properties whereas treatment T1 showed higher values in plant parameters only.

Keywords: wheat, plant parameters, organic carbon, bulk density, available NPK., etc.

Introduction

Wheat (*Triticum aestivum*) is a major cereal crop of the Indo-Gangetic plains of India. It is the most important staple food crop after rice in a global perspective. Wheat plays a major role in food and nutritional security with a prime share of up to 40% of total food grain production (Kumar *et al.*, 2017) [11]. Increasing the agricultural production relies significantly on a crucial factor viz. fertilizer use. The utilization of fertilizers in India has quickly increased over a span of four decades and the major reason for this is the adoption of high yielding and nutrient responsive cultivars (Hati *et al.*, 2008) [9]. Application of inorganic fertilizers has favorable implications in increasing crop yields. The soil physical environment can be affected by inorganic fertilizers by increasing the above ground and root biomass. This case happens through the innate property of inorganic fertilizers by which they provision of immediate nutrient supply to plants is facilitated in sufficient quantities (Lopez-perez *et al.*, 1990) [13]. Additionally, the organic matter content in soil is also increased (Bostick *et al.*, 2007) [2]. Inorganic fertilizers also reportedly influence increment in rooting depth and root proliferation in cereals (Brown *et al.*, 1987) [4]. This ultimately triggers the soil water transmission characteristic by influencing alteration of the pore geometry of the soil through dense and long rooted system of well fertilized plants (Schjonning *et al.*, 2005) [18]. However, the sole application of inorganic fertilizers supposedly decreased the stability of macro-aggregates and moisture retention capacity and increase in bulk density (Sarkar *et al.*, 2003) [16]. So, the implementation of organic manure has been encouraged since it enhances the soil organic matter content directly and also promotes the physical and biological properties of soil indirectly (Shen *et al.*, 1997) [20]. The application of organic fertilizers possesses positive implications on soil through increasing its water holding capacity, improving the soil structure and microbial activity, while decreasing the bulk density of soil (Hati *et al.*, 2007) [8]. In modern agriculture, while keeping in mind the status of soil health, it has been clarified that only organic fertilizers or chemical fertilizers individually cannot compensate for the balanced amount of nutrients required by the plant to sustain production. Though the organic fertilizers do not perform immediate changes as their chemical counterparts, their utilization can increase the efficiency of fertilizer use and also enhance the physico-chemical properties of the soil on a long term basis. In this study, we aim to find out the best combination of organic and inorganic fertilizers to obtain an efficient dosage so that the soil physical and chemical properties can be improved along with efficient production of the crop.

Materials and Methods

The experiment was conducted during the *Rabi* season of 2018-19 in the experimental field of Department of Soil Sciences, Lovely Professional University, Punjab. The experiment was laid out in a Randomized Complete Block Design having 7 treatments replicated 3 times. The experiment consisted of six fertilizer levels and one control, T0 being the control, T1 as 100% RDF (Recommended dose of fertilizer), T2 as 75% RDF+PSB (phosphate solubilizing bacteria), T3 as 50% RDF, T4 as 5 tha^{-1} vermicompost, T5 as 75% RDF+5 tha^{-1} vermicompost and T6 as 50% RDF+2.5 tha^{-1} vermicompost.

Climate: Phagwara has a humid subtropical and semi-arid climate which is characterized by extreme temperatures in both summers and winters. Hot and dry summer encompasses April to June, hot and humid climate from July to September, cold winters from November to January and mild climate from February to March. The maximum temperature during summer reaches 48 °C and minimum of 25 °C. During winter, maximum temperature reaches 19 °C and minimum of -1 °C. The average annual rainfall varies from 500-750 mm and major portion is received from July to September due to the South-West monsoon.

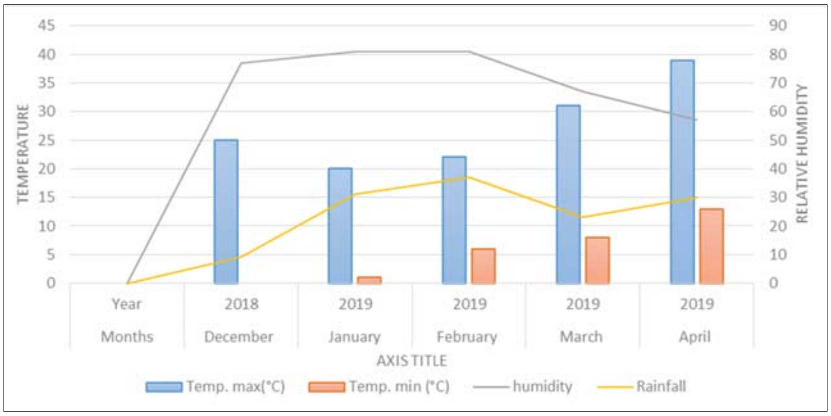

Fig 1: Meteorological data of the growing season

Initial soil parameters: The soil of the experimental field was sandy clay loam in texture containing 63.70% sand, 14.18% silt and 22.12% clay. The bulk density and particle density were 1.46 gcm^{-3} and 2.48 gcm^{-3} respectively. The crop was fertilized with NPK as basal dose in the form of neem coated urea, single super phosphate and muriate of potash, as prescribed in the treatments. Vermicompost was also utilized as a form of organic amendment in the treatments. The seeds were sown in lines with a seed-cum-fertilizer drill at a depth of 5 cm and spacing of 20 cm per row. For securing good yield, a seed rate of 98.8 $kgha^{-1}$ was used and sowing was done on the first week of December.

Five plants were selected at randomly from each plots and tagged in order to determine the plant parameters. The soil analysis was performed according to standard methods. The initial soil sample was collected at a depth of 0-30 cm., thereafter analysis provided the results of pH, EC, OC and available N, P, K as 7.43, 0.15 dSm^{-1}, 0.40% and 54.36 $kgha^{-1}$, 11.64 $kgha^{-1}$, 273.75 $kgha^{-1}$ respectively. In general, the experimental soil was low in N, medium in P and K.

Table 1: Initial soil parameters

Characters	Value	Rating	Method used
pH	7.43	Normal	pH meter (Sparks 1996)
EC (dSm-1)	0.15	Normal	Conductivity meter (Sparks 1996)
OC (%)	0.40	Low	Walkley and Black’s rapid titration method (Piper 1966)
Available N (kg ha-1)	54.36	Low	Micro-Kjeldahl method (Jackson 1973)
Available P (kg ha-1)	11.64	Medium	0.5N sodium bicarbonate extractable P (Olsen et al., 1954)
Available K (kg ha-1)	273.75	Medium	Ammonium acetate extractable K (Jackson 1967)

Results and Discussions

The fertilizer doses give significant effect on chemical properties of soil as well as growth parameter and yield attributes of crop, as tabulated and depicted below.

Chemical studies of soil: The soil chemical properties of soil in each treatments were studied during research work, aiming to evaluate the dynamic changes and effect on crop growth and yield parameter which is shown in table 2 and thoroughly discussed.

pH: The soil pH decreased in the treatments from the initial value. The maximum decline in pH was observed in the integrated treatment T5 with a decline of 3.19% from the initial pH value of 7.45. Similarly, the other treatments also observed significant decline in soil pH. The decline in soil pH might have been a resultant of the organic matter build up and decomposition in the fertilized plot. The unfertilized control plot T0 (7.34) observed no significant decrease in pH as compared to the other treatments. The higher reduction in pH on treatment T5 (7.20) than inorganic treatment T1 (7.24) might have been attributed to higher production of CO_2 and organic acids by the organic manures. Singh *et al.*, 2017 [23] also found maximum decrease in pH in the combined organic and inorganic treatment and also theorized that the release of organic acids during decomposition might cause decrease of pH. These studies are similar to and supported by the findings of Yaduvanshi *et al.*, 2003 [26] and Brar *et al.*, 2015 [3].

Electrical conductivity: The observation from all the treatments provides information on the slight increase of EC values from the original soil sample. The values of EC in all the treatments were less than 0.8 dS m^{-1} which is considered as safe for growing of all crops (Brar *et al.*, 2015) [3]. The increase of soil EC would be possibly due to the increase in base saturation of the soil where ideal doses of fertilizers and manures were applied. Also, the increase in soil EC at treatment T4 might be due to the decomposition of organic materials and releasing acids which reacted with the soluble salts already present in soil, thus converting the decomposed materials into soluble salts. The results can be backed up by the findings of Sarwar *et al.*, 2008 [17] and Hati *et al.*, 2007 [8].

Organic carbon: The highest value of organic carbon was observed in the sole organic treatment T4 (0.59%); which is closely followed by the treatment T2 (0.58 %) and calculative differential value of 1.72% was seen between treatments T4 and T2. The combined treatments of organic and inorganic fertilizers viz. T5 (0.55%) and T6 (0.53%) were also high in organic carbon content as compared to the sole inorganic treatment. The minimal value of OC was observed in the control treatment (0.23%) with small variations in the observed values during the growing season which might be due to its untreated nature. The OC in the soil increases; which was perhaps a result of start in humus formation and carbon sequestration activity. It was also observed that the application of vermicompost alone and in combination with inorganic fertilizers and PSB increased the organic carbon content, which is similar to the findings of Wolie *et al.*, 2016 [25]; Rasool *et al.*, 2008 [15]; Devi *et al.*, 2013[6]. It might be due to the balanced fertilization leading to better plant growth and root biomass, which adds the soil OC.

Available N: From the data, the maximum value of available nitrogen was observed in the inorganic treatment during the analysis period. T1 (112.90 kg ha^{-1}) leads the combination of inorganic and PSB treatment T2 (108.72 kg ha^{-1}) by 8.3%. The control treatment T0 (33.45 kg ha^{-1}) is significantly low as compared to the inorganic treatment T1. Similar studies can be observed from Kumar *et al.*, 2018[12]; Singh *et al.*, 2017[23] where the RDF treatment is superior to the organic treatments or the combined organic and inorganic treatments. The increase in Av. N might be due to the external application of organic and inorganic fertilizers along with PSB which enhances the activity of some microbial populations.

Available P: The maximum available phosphorus at the end of the observations is established in the inorganic and bio-fertilizer treatment T2 (17.56 kg ha^{-1}). The combined organic and inorganic treatment T5 gave the second maximum result of 16.21 kg ha^{-1}. A difference of 8.32% can be observed between the treatments T2 and T5. The other treatments also provided significant results. The available phosphorus in the soil may be also be observed as T2> T5> T3> T1> T6> T4> T0. A significant difference can be seen between the control treatment T0 and the best treatment T2. There was steady increase in the observed values during the growing season which might have been due to the decrease in pH and decline in pH positively impacts the availability of phosphorus. Also the addition of PSB might have significant effect on the gradual increase of av. P as the microbial decomposition slowly takes place on the organic matter, which in turn might help in solubility of native phosphates (Khan *et al.*, 1984) [10]. However, the inorganic treatment T1 was found to be comparably less as compared to the other combined treatments which might be due to lack of organic matter and thus, depletion of the native P pool occurs. Similar results were obtained from Devi *et al.*, 2013[6] whose available phosphorus content in inorganic treatments was lower compared to the integrated inorganic and organic treatments.

Available K: Available K in the treatment T2 was considered to be maximum at a range of 284.16 kg ha^{-1} during the growing season of the crop. Significant variations were also observed in the other treatments. After treatment T2, the apparent observations illustrated by treatment T1 had the second highest values at 272.95 kg ha^{-1}. The two treatments T2 and T1 observed a difference of 0.41 %. The combined treatment of organic and inorganic fertilizer in treatment T5 also impacted the available K in soil with significant high values comparable to treatments T2 and T1. The buildup of available K in these treatments might be due to the addition of organic fertilizers and additional K obtained from them through solubilizing action of certain organic acids produced during organic decomposition (Yaduvanshi., 2003) [26]. Minimal observation was recorded in the control treatment T0. Supporting results were noticed on the findings of Devi *et al.*, 2011[5] and Devi *et al.*, 2013[6] in which the integrated treatment inorganic and bio-fertilizers provided a much buildup of available potassium.

Table 2: Soil parameters as an effect of differential fertilizer dosage after the harvest of the crops

Treatments	pH	EC (dSm^{-1})	OC (%)	Av. N ($kgha^{-1}$)	Av. P ($kgha^{-1}$)	Av. K ($kgha^{-1}$)
T0	7.34	0.23	0.26	33.45	10.98	205.64
T1	7.24	0.28	0.46	112.90	15.40	272.95
T2	7.27	0.26	0.55	108.72	17.56	284.16
T3	7.26	0.31	0.39	91.99	15.34	265.47
T4	7.33	0.28	0.59	83.63	13.33	229.95
T5	7.20	0.27	0.53	87.81	16.21	269.21
T6	7.27	0.27	0.51	83.63	14.62	250.51
SE(m)±	0.081	0.005	0.013	5.551	0.271	9.749
C.D. at 5%	0.253	0.016	0.040	17.293	0.844	30.372
C.V.	1.841	3.274	4.624	11.177	3.139	6.648

Plant Growth Parameters

Plant height: The plant height is not a factor promulgated by the yield factors, mostly in grain crops. But the effect of certain nutrients on plant metabolism can be identified. The 100% RDF treatment T1 elucidates maximum plant height of 104.33 cm; which is followed up by the integrated treatment T5 at 93.50 cm as shown in table 3. Singh *et al.*, 2018[21] also showed similar findings whereby the recommended fertilizer treatment provided maximum results. A variation of 11.58% in plant height can be observed between the two treatments T1 and T5. The differential dosage of fertilizers input might have impacted the metabolism of plants and the availability of nutrients. Meena *et al.*, 2013 [14] also suggested that the increase in plant height in response to combined application of organic and inorganic fertilizers might be due to enhanced availability of macronutrients and micronutrients.

Plant population: The plant population increased with the application of organic and inorganic amendments. The maximum value was obtained in T1 treatment (145.27 m^{-2}) which shows a 18.05% more plant population than vermicompost treatment T4 (123.05 m^{-2}) whereas the minimum value was obtained in the control treatment T0 (81.94 m^{-2}). Among the other treatments, significant higher plant population was observed in T5, T3 and T2 treatments (117.50 m^{-2}, 106.66 m^{-2} and 105.00 m^{-2} respectively) as compared to T0 as shown in table 3. Availability of easily extractable nutrients when compared to other treatments might have factored the maximum plant population in the inorganic. The similar results were obtained by Singh *et al.*, 2018[21] and reported that a better plant population, plant height, leaf area index, etc. due to the easy availability of extractable nutrients.

Spike length: The longest spike length was measure in treatment T2 (8.54 cm) followed closely by T6 (8.32 cm). A difference of 2.64% can be observed between treatments T2 and T6. Treatments T5 and T1 followed a medium measurements of 7.65 cm and 7.11 cm respectively. The shortest spike length occurs in control treatment T0 (5.55 cm). Singh *et al.*, 2018[21] also found similar findings which suggested that the results might be due to the integration of organic and inorganic sources.

Spikelet number per spike: The spikelet number per spike (50.00) was recorded to be maximum in 50% RDF+ 2.5tha^{-1} vermicompost. The treatments T2, T5 and T3 closely followed the preceding treatment T6 by mean values of 49.33, 48.00 and 47.33 respectively. The control plot T0 (29.11) was observed to possess the minimum recorded value. Increase of 71.40% of spikelet number per spike was analyzed in T6 as compared to control treatment. The results overlap with the findings of Singh *et al.*, 2018[21] whereby the combined application of inorganic, bio fertilizer and vermicompost gave the highest statistics in spikelet number per spike.

Tiller number: During the assessment for tiller number, treatment T1 was considered having the maximum number of tillers (799.03) as compared to the other treatments. Treatment T5 had the second highest number of tillers (548.33). Treatments T2, T6, T3 and T4 vary significantly and follow with the numbers of tillers counting 577.50, 500.74, 478.78 and 430 respectively. The control plot T0 was observed with the minimum number of tillers (286.80). The supposed findings were also similar with the findings of Hashimi *et al.*, 2015[7] which shows maximum tillering at 100% RDF and minimum at control.

Plant fresh weight: The maximum plant fresh weight can be observed in treatments T1 and T5. The result shows treatment T1 and T5 values being on par with one another with a mean value of 116.00. An increase of 65% was observed from the control treatment T0, which had the lowest value of 70.00. The combined application of 75% RDF and vermicompost might have a significant response to the plant fresh weight which were similarly obtained from the research of Shah *et al.*, 2006[19] and Hashimi *et al.*, 2015[7].

Table 3: Plant growth parameters as an effect of the differential fertilizer dosage

Treatments	Plant height (cm)	Plant Population per m^2	Spike length (cm)	Spikelet no. per spike	Tiller number	Plant fresh weight (qha^{-1})
T0	63.00	81.94	5.55	29.11	286.80	70.00
T1	104.33	145.27	7.11	43.33	799.03	116.00
T2	88.71	105.00	8.54	49.33	577.50	115.67
T3	90.25	106.66	8.16	47.33	478.78	100.66
T4	64.33	123.05	5.94	32.66	430.70	87.67
T5	93.50	117.50	7.65	48.00	548.33	116.00
T6	77.00	93.88	8.32	50.00	500.74	110.33
SE(m)±	0.887	1.620	0.146	0.869	28.942	2.315
C.D. at 5%	2.762	5.048	0.454	2.707	90.167	7.211
C.V.	1.850	2.540	3.441	3.514	9.638	3.918

Harvest parameters

Grain no. per spike: The grain number per spike was maximum in treatment T6 (45.44) which is closely followed by treatment T2 (44.89) as shown in table 4. A differential value of 1.22% was observed between the two treatments. The minimum was observed the control treatment T0. Similar observations were made in the findings of Singh *et al.*, 2018[22].

Thousand grain weight: The thousand grain weight was observed to be the maximum in treatment T1 (42.67) which is closely followed by treatment T5 (40.67). The other treatment values also vary significantly with one another. A differential value of 4.91% was observed between the two maximums. The minimum value was observed in control treatment T0. Similar findings were observed from Biswakarma *et al.*, 2018 [1] and Verma *et al.*, 1997 [24].

Grain yield: The maximum grain yield was obtained in treatment T1 (57.33) which is closely followed by treatment T2 (56.67). A differential value of 1.16% is observed between the treatments T1 and T2. The minimum grain yield was observed in the control treatment T0 (35.67). The grain yield is a factor of weight of individual grains and the application of 100% RDF resulted in higher tillering number and weight of 1000 grains. Findings of Verma *et al.*, 1997[24] were also similar to these findings.

Harvest index: The harvest index was not significantly affected by the different fertility treatments. A maximum harvest index of 67.72 was observed in treatment T4 which was on par with the control treatment T0 presented in table 4. Minimum harvest index value of 63.36 was observed in treatment. Similar observations were found in Verma *et al.*, 1997 [24] and Singh *et al.*, 2018 [22].

Dry matter production: Dry matter production value was maximum in treatments T1 and T5 whose result 87.33 qha^{-1}. The second maximum value was obtained in treatment T2 with a value of 85.00 qha^{-1}. A differential value of 2.74% was observed between the two maximum values. The high value of dry matter production in T5 which was on par with T1 is probably due to positive effect of organic and inorganic fertilizers treatments. Noted readings were similar in terms of observations by Singh *et al.*, 2018[22] and Verma *et al.*, 1997[24].

Table 4: Plant harvest parameters as an effect of the differential fertilizer dosage

Treatments	Grain no. per spike	Thousand grain weight (g)	Grain yield (qha^{-1})	Harvest index	Dry matter production after harvest (qha^{-1})
T0	25.56	23.93	35.67	67.72	52.67
T1	40.44	42.67	57.33	65.65	87.33
T2	44.89	38.39	56.67	66.67	85.00
T3	43.66	37.54	50.33	66.52	75.67
T4	29.44	38.09	44.33	67.51	65.67
T5	43.66	40.67	55.33	63.36	87.33
T6	45.44	34.91	53.33	64.52	82.67
SE(m)±	0.967	0.165	1.407	0.310	1.825
C.D. at 5%	3.013	0.515	4.383	0.965	5.686
C.V.	4.293	0.782	4.832	0.808	4.126

Conclusion

It can be concluded that the integrated treatment 75% RDF + 5 tha^{-1} vermicompost can be considered as the best treatment produced significant effect on plant height, plant populations, maximum plant fresh weight and dry matter production and minimum harvest index, which suggests more economic yield and also concluded that the physicochemical parameters has been significantly affected by the combination of RDF and vermicompost.

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