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Influence of Integrated Use of Organic Manures and Inorganic Fertilizers on Physio-chemical Properties of Soil and Yield of *Kharif* Maize in Coarse Loamy Typic Haplustept Soil

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ABSTRACT

Background: Applying inorganic fertiliser can boost crop output, but protecting the environment for future generations is burdensome, especially with the ongoing rise in global population. It is possible to achieve sustainable agricultural yield by using fertilisers, both organic and artificial, in a strategic way. Parts of inorganic fertilisers could be replaced with organic fertilisers in order to preserve and boost soil productivity and increase crop yield.

Methods: The two year field experiment was conducted at experimental farm at Lovely Professional University, Phagwara, Punjab during the *kharif* season 2019- 2020 to study the influence of integrated use of organic manures and inorganic fertilizers on physio-chemical properties of soil and yield of maize in coarse loamy Typic Haplustept soil with 8 treatments treatments T_1- Control, T_2 (125:60:30) kg ha^{-1}, T_3- RDF +10 ton farmyard manure ha^{-1}, T_4- 75% RDF+10 ton farm yard manure ha^{-1}+Vermicompost @ 2 ton ha^{-1}, T_5-75% RDF+10 ton farmyard manure ha^{-1}, T_6- 50% RDF +10 ton farm yard manure +vermicompost@ 2 ton ha^{-1} + azotobacter ha^{-1}, T_7-50% RDF +15 ton of farmyard manure +azotobacter ha^{-1}, T_8-25 % RDF + azotobacter + vermicompost@ 2 ton ha^{-1} in RBD design with 3 replications.

Result: The soil pH was found highest in T_2 (RDF (125:60:30) kg $ha^{-1)}$ (7.41) whereas highest EC was found in T_2- RDF (125:60:30) kg ha^{-1} (0.23 dSm^{-1}). The highest bulk density found under T_1 (Control) (1.83 g cm^{-3}) and porosity was highest in T_6 (50% RDF +10 ton farm yard manure + vermicompost@ 2 ton ha^{-1} + azotobacter ha^{-1}) (36.66%). In T_6 (50% RDF +10 ton farm yard manure + vermicompost@ 2 ton ha^{-1} + azotobacter ha^{-1}), the highest amount of nitrogen (312.3 kg ha^{-1}), phosphorus (25.6 kg ha^{-1}), potassium (285.33 kg ha^{-1}) and organic carbon (5.6g kg^{-1}) was found. In terms of yield parameters, the grain yield (4223 kg ha^{-1}), straw yield (5266 kg ha^{-1}), harvest index (41.53%) and 1000-seed weight (286.66 gm) was found highest in T_6 (50% RDF +10 ton farm yard manure + vermicompost @ 2 ton ha^{-1} + azotobacter ha^{-1}). There are significant difference in all the treatements with respect to the physico-chemical properties of soil and yield paramters of maize.

Key words: Azotobacter, Bulk density, Physio-chemical properties, Straw and grain yield, Vermicompost.

INTRODUCTION

Maize is one of the important cereal crops after wheat and rice. It is basically used as food by humans and feed by animals. It is known as a queen of cereals due to its high yield capacity. It is cultivated widely in different countries like USA, Canada, Malaysia, Singapore, India *etc*., because it has a potential as value added product for export. t is the most versatile crop with wider adaptability in varied agri-ecologies and has highest genetic yield potential among food grain crops. It is used in the manufacturing of different products like plastics, dye, boot polish, starch, adhesive, rayon etc. Due to its large uses it is also called as miracle crop. During the year 2018-19, the area under maize crop was (9.03 m ha), production recorded (27.72 mt) and productivity was (30.7 q ha^{-1}). The planting of maize at optimum plant density leads to high dry matter and biomass production. Geographically, the leading state in production of *kharif* maize is Uttar Pradesh whereas Bihar ranks first in cultivation of *Rabi* Maize. It has been assumed that a sensible use of organic and inorganic fertilizer sources in a combination, nurture the prolonged soil fertility and encourage uttermost level of productivity (Baghdadi *et al.,* 2018). Till date some of the experiments conducted at various locations following different cropping systems which showed inorganic fertilizers sole application deteriorate the quality of soil which leads to unsustainable crop yield (Kiboi *et al.,* 2019).

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The integration of organic and inorganic fertilizer sources was required to achieve the sustainability of agroecosystem (Bayu, 2020). The combination of chemical fertilizers along with organic manures resulted in higher productivity and stabilizing the crop production. The application of organic manure enhanced the crop yield due to increase in nutrient availability and improvement in soil structure. Organic manures bind the soil aggregates which increased cation exchange capacity, phosphate availability and water holding capacity of soil. They also improved the fertilizer use efficiency, microbial and organic carbon content in the soil. The nitrogen loss was also less in soil due to the application of organic manures (Liu *et al.,* 2021). The regular application of inorganic fertilizers along with organic manures helped in controlling the pH and EC of soil as compared to without organic manure application (Han *et al.,* 2021). The combination of organic manures with inorganic fertilizers resulted in improvement of soil fertility and available nitrogen status of soil (Han *et al.,* 2021). The application of Phosphorus along with FYM also helpful in the improvement of organic carbon content of soil (Arif *et al.,* 2021).

The application of farmyard manure along with recommended dose of fertilizers resulted in higher economical (grain) yield. The application of NPK (20:0:10 kg ha^{-1}) along with poultry manure (30 tons) resulted in enhancing the grain yield of maize (Islam *et al.,* 2021). There wass a development in root growth of maize by using farm yard manure and poultry manure. The combined application of vermicompost with inorganic fertilizers made the availability of nutrients to crop throughout their growth period and it results in improvement of crop yield as well as physical, chemical and biological properties of the soil. By keeping in view this existing scenario, a field experiment conducted to study the influence of integrated use of organic manures and inorganic fertilizer on physio-chemical properties of soil and yield parameters of *kharif* maize in coarse loamy Typic Haplustept soil.

MATERIALS AND METHODS

The two year experiment was conducted at School of Agriculture, Experimental Farm at Lovely Professional University at Phagwara, Punjab during 2019-2020. The farm was situated at latitude 31.25°N and longitude 75°E as per goggle map coordinates along with altitude of above 232m above mean sea level. The two year experiment was laid down in 8 treatments and 3 replications.The treatments were T_1- Control, T_2- RDF (125:60:30) $kgha^{-1}$, T_3- RDF +10 ton farmyard manure ha^{-1}, T_4- 75% RDF + 10 ton farm yard manure ha^{-1} + Vermicompost @ 2 ton ha^{-1}, T_5-75% RDF + 10 ton farmyard manure ha^{-1}, T_6- 50% RDF +10 ton farm yard manure + vermicompost @ 2 ton ha^{-1} + azotobacter ha^{-1}, T_7- 50% RDF +15 ton of farmyard manure + azotobacter ha^{-1} , T_8-25 % RDF +azotobacter + vermicompost @ 2 ton ha^{-1}. The total number of plots were 24. The size of each plot was $20m^2$. The variety used was PMH-2255.The soil of the site where experiment was conducted were classified as coarse loamy mixed hyperthermic family of Typic Haplustept. Soil pH and EC was measured by the procedure given by Jackson (1973). Available soil N was estimated by alkaline potassium permanganate method where organic matter in soil has been oxidized by hot alkaline potassium permanganate solution. During oxidation the evolved ammonia was distilled and trapped by boric acid and mix indicator. The NH_3 which was trapped measured by procedure given by Subbiah and Asija (1956). Available soil phosphorous was analysed with sodium bicarbonate ($NaHCO_3$) at 8.5 pH (Olsen's reagent) and the amount of phosphorous in the extract was analysed by chlorostannous reduced phosphomolybdate blue colour method using spectrophotometer at 660 nm (Olsen *et al.,* 1954). Available soil potassium was analysed by using flame photometer (Jackson, 1973). Prosity % os soil calculated by =

$$1-\frac{BD}{PD} \times 100$$

Where particle density is 2.65 gcm^{-3} Initial basic characteristics of tested experimental soil were pH- 7.08, electrical conductivity 0.18 dSm^{-1}, available N-147 $kgha^{-1}$ available P_2O_5-15.71 $kgha^{-1}$ available K_2O- 172 $kgha^{-1}$. The harvested product of individual plot was tied in bundles and left in field for 3-4 days for drying and weight the product to get biological yield. The straw yield was measured by subtracting the grain yield from biological yield. The yield of per plot was converted into $kgha^{-1}$.

RESULTS AND DISCUSSION

Soil parameters

Bulk density and porosity

The mass of soil per unit volume including pore space is known as bulk density. Compactness and porosity of soil is indicated by bulk density. The combined application of manures and fertilizers decreased the bulk density of soil. The results showed that the highest bulk density was recorded in the control which remains same during both years. The bulk density was decreased in those plots which amended with manures and fertilizers as compared to control and sole NPK fertilizers. Bulk density (g cm^{-3}) ranged from 1.68 to 1.83 gcm^{-3}. The control plot bulk density same as initial value during first year but slightly increased during second year of study. The minimum bulk density (1.68 g cm^{-3}) was recorded in T_6- 50% RDF+10t FYM+V.C@ 2 tha^{-1} + azotobacter ha^{-1} followed by T_7-50% RDF+15t FYM+azotobacter ha^{-1} (1.69 g cm^{-3}) (Table 2). That might be due to manures which affect soil physical properties which significantly lowered bulk density and enhance porosity. All the treatments were shown non-significant difference from each other. The maximum bulk density (1.83 g cm^{-3}) recorded in the control during both years. The porosity (%) was significant among treatments. The change in porosity (%) was recorded after the application of manures and fertilizers to soil. The minimum porosity (31%) recorded in the control followed by T_1 (100% RDF) having 31.22% porosity. The maximum porosity (36.66 %) and T_7- 36.22% was recorded in T_6- 50% RDF+10 t FYM+V.C@ 2 t ha^{-1}+ azotobacter ha^{-1} followed by T_8- 25% RDF+ azotobacter + V.C@ 2 t ha^{-1} with 35.96% (Table 2). The interaction of FYM and RDF exerted positive effect on the accumulation of soil organic matter. As the soil organic matter increased porosity increased and bulk density reduced. This result is in confirmity with the findings of John *et al.* (2021); Li *et al.* (2020) and Liu *et al.* (2021). Kiboi *et al.* (2019) observed that the improvement in soil physical properties of soil was due the presence of an organic acid which formed organominerals. These organominerals resulted soil aggregation and added functional components of organic matter to soil.

pH

Soil pH is considered as an important soil health indicator. Variations in pH of soil after integrated application of manures and fertilizers were statistically different among treatments. pH ranged from 7.30 to 7.41 where highest (7.41) pH recorded in T_2- RDF (125:60:30) $kgha^{-1}$ followed by T_6- 50% RDF+10 t FYM+V.C@ 2 t ha^{-1}+ azotobacter ha^{-1} and lowest (7.3) recorded in the control (Table 1). Low pH in the control might be due to secretion of organic acids which caused reduction in pH. The combination of FYM+ RDF resulted increment in pH of soil that might be due to addition of organic matter which increased Cation exchange capacity and organic fractions of soil. The organic matter present in soil contains colloids which bind up the cations and increase in pH of soil (Toková *et al.,* 2020).

Soil EC

Electrical conductivity is a measure of soil salinity and ability of soil solution to carry charges (Kumari *et al*., 2014). EC can be used as an indicator of ionic strength (Olowoboko *et al*., 2018) by estimating the amount of dissolved salts in soil solution. Release of nutrient from organic material and mineralization processes responsible for increase in salt uptake of soil. EC value of soil significantly varied among treatments. EC value ranged from 0.15 to 0.23 dS m^{-1}. The maximum value (0.23 dSm^{-1}) observed in T_2- RDF (125:60:30) $kgha^{-1}$ which was at par with T_6, T_3, T_4 (0.20 dSm^{-1}). The lowest value (0.15 dSm^{-1}) was recorded in the control (Table 1). Presence of more amount of alkaline metal *i.e.*, Ca^{2+}, Mg^{2+} and K^{+}) in FYM responsible for increase in EC of soil (Mardamootoo *et al.,* 2021 and Rao *et al*., 2002).

Available N

Soil available nutrient status also varied with integrated application of manures and fertilizers. Soil available N was maximum (312.3 $kgha^{-1}$) in 50% RDF+10t FYM+V.C@ 2t ha^{-1}+ azotobacter ha^{-1} and lowest in the control (147.66 $kgha^{-1}$) (Table 1). All the treatments showed significantly more

Table 1: Effect of integration of organic manure and inorganic fertilizer sources on chemical properties of soil during 2019-2020 (pooled data).

Treatments	pH	EC (dSm^{-2})	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
T_1- Control	7.30^{b}±0.20	$0.15a^{b}$±0.01	147.66 ^{g}±1.24	10.37^{f}±1.69	102.83^{g}±1.22
T_2- RDF (125:60:30) kg ha^{-1}	7.41^{a}±0.08	0.23^{a}±0.008	261.16^{f}±0.84	18.21^{e}±1.63	192.33^{f}±2.05
T_3- RDF (125:60:30)+10 tFYm ha^{-1}	7.35^{a}±0.08	0.20^{a}±0.008	266.66^{e}±1.24	20.23^{d}±1.13	212.00^{e}±1.63
T_4- 75% RDF+10 tFYM+V.C@2 t ha^{-1}	7.39^{a}±0.21	0.20^{a}±0.01	294.7^{c}±0.96	21.3^{c}±1.11	253.33^{c}±2.21
T_5- 75% RDF+10 tFYM ha^{-1}	7.34^{a}±0.08	0.19^{a}±0.009	292.03^{cd}±1.02	20.65^{d}±1.43	266.00^{d}±1.10
T_6- 50%RDF+10 tFYM+V.C@2 tha^{-1}+ azotobacter ha^{-1}	7.39^{a}±0.08	0.18^{a}±0.02	312.3^{a}±1.04	25.6^{a}±1.49	285.33^{a}±1.70
T_7- 50% RDF+15tFYM+azotobacter ha^{-1}	7.37^{a}±0.04	0.19^{a}±0.008	302.23^{b}±1.11	23.5^{b}±1.35	265.67^{b}±1.84
T_8- 25% RDF+azotobacter+V.C@ 2t ha^{-1}	7.34^{a}±0.12	0.20^{a}±0.01	295.36^{c}±0.74	22.8^{bc}±0.91	256.00^{d}±1.19

Table 2: Effect of integration of organic manure and inorganic fertilizer sources on physical properties of soil during 2019-2020 (pooled data).

Treatments	Organic carbon (gkg^{-1})	Bulk density (gcm^{-3})	Porosity (%)
T_1- Control	3.4^{f}±0.002	1.83^{a}±0.05	31^{b}± 2.22
T_2- RDF (125:60:30) kg ha^{-1}	3.9^{e}±0.003	1.82^{a}±0.03	31.32^{b}±3.41
T_3- RDF (125:60:30)+10 tFYm ha^{-1}	4.2^{d}±0.008	1.74^{a}±0.05	34.3^{a}±3.21
T_4- 75% RDF+10 tFYM+V.C@2 t ha^{-1}	4.3^{cd}±0.005	1.71^{a}±0.03	35.47^{a}±4.2
T_5- 75% RDF+10 tFYM ha^{-1}	4.6^{bc}±0.001	1.73^{a}±0.03	34.7^{a}±3.56
T_6- 50%RDF+10 tFYM+V.C@ 2 t ha^{-1}+azotobacter ha^{-1}	5.6^{a}±0.002	1.68^{a}±0.04	36.6^{a}±4.5
T_7- 50% RDF+15 tFYM+azotobacter ha^{-1}	4.7^{b}±0.009	1.69^{a}±0.04	36.22^{a}±5.5
T_8- 25% RDF+azotobacter+V.C@ 2 t ha^{-1}	4.4^{cd}±0.008	1.72^{a}±0.07	35.96^{a}±6.5

available N as compared to the control. As the farm yard manure and vermicompost organic matter components starts to decompose, nutrients were released to soil and increase the availabilty of N. Soil inorganic N increased with integrated use of manures and fertilizers was observed which could be due to decrease in leaching of N with increase in available N. The availability of N in soil was increased that might be due to the improvement in physical conditions of soil microbial biomass and contribution of N by added quantity of FYM. Fertilizers combine with vermicompost also showed significant effect on soil available N it might be due to the vermicompost as it contains organic acids, hormones and microorganisms which stimulate microbial activity in soil (Dias *et al*., 2010).

Available phosphorous

Significant differences in changes of available P were found among treatments (Table 1). After the harvesting of maize crop highest available P was found in soils of T_6-50% RDF+10t FYM+V.C@ 2t ha^{-1}+ azotobacter ha^{-1} (25.6 kg ha^{-1}) followed by T_7-50% RDF+15t FYM+ azotobacter ha^{-1} (23.5 kg ha^{-1}) and minimum available P (10.37 kg ha^{-1}) was recorded in the control. Interaction of FYM with biochar and synthetic fertilizers was found significant. It increased the availability of P in soil might be due to the production of organic acids in soils by FYM which release more P from SSP (Han *et al.,* 2021 and Islam *et al.,* 2021)

Available potassium

Available K in soil was significantly different from each other during both years (Table 1). After harvesting maize the highest available K (285.33 kg ha^{-1}) was found in T_6-50% RDF+10t FYM+V.C@ 2t ha^{-1}+ azotobacter ha^{-1}. The second highest (265.67 kg ha^{-1}) available K was found in T_7-50% RDF+15tFYM+azotobacter ha^{-1}. The lowest available K was recorded in T_1- (the control)-102.83 kg ha^{-1} followed by T_1 (100% RDF)- 192.33 kg ha^{-1}. The other treatments were statistically comparable with the control. Available K uptake was significantly affected by the addition of organic matter in soil. It could be due to higher mineralization of potassium at more levels of organic matter. This result is also supported by Guo *et al*. (2021).

Organic carbon (gkg^{-1})

Soil carbon is the driving agent of soil organic matter uptake and soil quality. SOC is a heterogeneous mixture of organic substances. Organic carbon was found highest in T_6- 50% RDF+10t FYM+V.C@ 2t ha^{-1}+ azotobacter ha^{-1} (5.6 g kg^{-1}) and second highest OC (4.7 g kg^{-1}) was found in T_7 - 50% RDF+15 FYM+azotobacter ha^{-1} (Table 2). The lowest (3.4 gkg^{-1}) was found in T_0 (the control). All the treatments were significantly different among themselves. FYM addition enhanced the quantity and quality of SOM. This result is also supported by Baghdadi *et al.* (2018) and Tabbasum *et al.* (2021).

Yield parameters

Grain yield and Straw yield

During two years of experiment, the highest grain yield is obtained in T_6 (50% recommended dose of fertilizer +10 ton farm yard manure + vermicompost@ 2 ton ha^{-1} + azotobacter ha^{-1}) followed by T5 and T_7 (50% recommended dose of fertilizer +15 ton of farmyard manure + azotobacter ha^{-1}). Due to high uptake of nutrients, grain numbers cob^{-1} was increased which results in high grain yield at maturity. The lowest grain yield was found in T_1 (Control) as there was no application of organic and inorganic fertilizers (Table 3). These results are confirmed with findings of (Xiao *et al.,* 2020). The maximum straw yield is found under T_6 (50% recommended dose of fertilizer +10 ton farm yard manure + vermicompost@ 2 ton ha^{-1} + azotobacter ha^{-1}) followed by T_7 (50% recommended dose of fertilizer +15 ton of farmyard manure + azotobacter ha^{-1}) (Table 3). The combination of organic manures with inorganic fertilizer shows positive effect which results in increased biomass of maize in T_6 (50% recommended dose of fertilizer +10 ton farm yard manure + vermicompost@ 2 ton ha^{-1} + azotobacter ha^{-1}). The lowest amount of straw yield was found under T_1 (Control) as we have not applied any fertilizer or organic manure source in this treatment. FYM in combination with synthetic fertilizers increase grain yield and straw yield because of slow and timely release of nutrients and reduce N losses. Increase in yield of crops attributed to nutritional value of which increased soil fertility and productivity and increase FUE mainly N fertilizer by

Table 3: Effect of integration of organic manure and inorganic fertilizer sources on Yield of kharif maize during 2019-2020 (pooled data).

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Test weight (gm)
T_1- Control	$2356.7^{fe}\pm98.41$	$4451.33^{f}\pm84.42$	$32.6^{d}\pm1.18$	$203.5^{g}\pm2.90$
T_2- RDF (125:60:30) kg ha^{-1}	$3946.2^{c}\pm88.16$	$5339.23^{c}\pm60.72$	$39.1^{b}\pm0.53$	$251^{f}\pm2.44$
T_3- RDF (125:60:30)+10 tFYm ha^{-1}	$3048.63^{d}\pm75.10$	$4393.66^{g}\pm42.89$	$34.7^{c}\pm0.53$	$252.7^{e}\pm1.06$
T_4- 75% RDF+10 tFYM+V.C@ 2 t ha^{-1}	$3971.1^{c}\pm30.68$	$4245.33^{h}\pm47.78$	$32.4^{d}\pm0.44$	$260.5^{c}\pm1.14$
T_5- 75% RDF+10 tFYM ha^{-1}	$4190^{b}\pm14.71$	$4503.33^{e}\pm71.91$	$35.2^{c}\pm0.65$	$280.7^{b}\pm1.22$
T_6- 50%RDF+10 tFYM+V.C@ 2 tha^{-1}+azotobacter ha^{-1}	$4223^{a}\pm89.82$	$5666^{a}\pm65.28$	$41.5^{a}\pm0.99$	$286.8^{a}\pm1.35$
T_7- 50% RDF+15 tFYM+azotobacter ha^{-1}	$4153.4^{b}\pm76.43$	$5485.33^{b}\pm29.78$	$39.1^{b}\pm0.49$	$255.3^{d}\pm0.89$
T_8- 25% RDF+azotobacter+V.C@ 2 t ha^{-1}	$3991.8^{c}\pm12.2$	$4703.33^{d}\pm68.85$	$35.3^{c}\pm0.29$	$281.8^{b}\pm1.24$

reducing leaching of N. These results are confirmed with the findings of (Ghosh *et al.,* 2020).

Harvest index

The harvest index was found highest in T_6 (50% recommended dose of fertilizer +10 ton farm yard manure + vermicompost@ 2 ton ha^{-1} + azotobacter ha^{-1}) due to the enhancement of soil physio-chemical properties by organic manures which contribute to highest value of harvest index (Table 3). The treatment T_7 (50% recommended dose of fertilizer +15 ton of farmyard manure + azotobacter ha^{-1}) and T_2 (100% recommended dose of fertilizer (125:60:30) kgha^{-1}) are statistically non-significant and at par with each other. The lowest harvest index was found in T_1 (Control) as in this treatment no application of any organic manure and inorganic fertilizer applied. The results are confirmed with the findings of (Félix *et al.,* 2020). The availability of nutrients influenced by enhancing CEC, improving soil pH and direct contribution of nutrients which increased crop growth and yield (Bala *et al*., 2019).

Test weight (g)

The weight of 1000 grains weight is called test weight which is an important yield attribute which gave the information regarding the efficiency of grain filling process. 1000 grain weight is the desired output which referred as one of the most important agronomic parameters which contribute in grain yield. The highest 1000- grain weight (test weight) was found in T_6 (50% recommended dose of fertilizer +10 ton farm yard manure + vermicompost@ 2 ton ha^{-1} + azotobacter ha^{-1}) because azotobacter enhance the availability of nitrogen in soil and it increase number of grains as well as 1000-grain weight (Table 3). The treatments T_7 (50% recommended dose of fertilizer +15 ton of farmyard manure +azotobacter ha^{-1}) and T_2 (100% recommended dose of fertilizer (125:60:30) kg ha^{-1}) are statistically non-significant and at par with each other. The lowest 1000-grain weight (test weight) was found in T_1 (Control) as in this treatment there was no application of organic and inorganic fertilizer sources. These results are confirmed with the findings of (Arif *et al.,* 2021).

CONCLUSION

The current study concluded that all the organic and inorganic fertilizer sources has significant effect on physio-chemical properties of soil and yield parameters of kharif maize. The integration of organic manures with inorganic fertilizer sources showed highest results in all the soil and yield parameters. The present study also indicated that it is not possible to maintain soil fertility and productivity by the sole application of either organic manure or inorganic fertilizer source. To sustain soil fertility and productivity on long term basis, the integration of organic and inorganic is highly recommended.

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