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RESEARCH ARTICLE
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Efficacy of fertilizer on vegetative and reproductive traits of spring rice under System of Rice Intensification (SRI)

Eficacia del fertilizante sobre las características vegetativas y reproductivas del arroz de primavera bajo el Sistema de Intensificación del Arroz

Supriya Niroula[1], Khem Raj Ghimire[1*], Melina Rai[1], Uma Devi Bhandari[1], Soniya Koirala[1], Chandani Sunuwar[1], Nabin Bhattarai[1], Nitesh Katuwal[2]

[1] G.P. Koirala College of Agriculture and Research Centre, Gothgaun, Morang, Nepal
[2] Madan Bhandari Memorial Academy, Urlabari, Morang

*Corresponding author: ghimireu13@gmail.com
https://orcid.org/0009-0009-1097-3758

Abstract

Rice is an important cereal crop and staple food of Nepal. The objective of this research was to identify the management of fertilizers that have relatively better performance and grain yield. Hence, a field study was conducted from February to July 2024 in the farmer's field at Biratnagar, Nepal in a Randomized Complete Block Design (RCBD) with seven treatments: T1= Nitrogen as Urea, T2= Potassium as MOP, T3= Phosphorus as SSP, T4 = NPK, T5 = Farm Yard Manure, T6= Mustard Oilseed Cake, and T7= Control, each replicated thrice. Growth parameters and yield parameters data were recorded. The study revealed significant variations in growth and yield parameters across the different fertilizer treatments. The highest plant height (73.33 cm) at 45 days after transplanting was seen in T4, which also showed the highest grain yield (7.04 $t.ha^{-1}$) and a significant number of effective tillers (29.43). The plots with NPK also had the highest number of tillers per unit area (21.03) whereas control had the lowest of 12.43. Conversely, the lowest grain yield (3.51 $t.ha^{-1}$) was observed in control plots, which also recorded the lowest plant height (47.20 cm) and straw yield (3.97 $t.ha^{-1}$). Incorporation of Farm Yard Manure and Mustard oilseed cake is strongly recommended along with NPK, as those treatments were also seen as excellent. If they are mixed with the NPK, the yield would potentially be increased as there would be positive interactions between them.

Keywords: *fertilizer, growth, management, manure, rice, yield*

Resumen

El arroz es un importante cultivo de cereales de Nepal, es el alimento básico de las personas que viven aquí. El objetivo de esta investigación fue identificar prácticas de manejo de fertilizantes que tengan un rendimiento superior y un mayor rendimiento de grano. Así, se llevó a cabo un estudio de campo de febrero a julio de 2024 en el campo del agricultor en Biratnagar, Nepal, en un Diseño de Bloques Completos Aleatorios (RCBD) con siete tratamientos: T1= Nitrógeno como Urea, T2= Potasio como MOP, T3= Fósforo como SSP, T4 = NPK, T5 = Estiércol de Corral, T6= Torta de Semillas Oleaginosas de Mostaza y T7= Control, cada uno replicado tres veces. Se registraron datos sobre parámetros de crecimiento y parámetros de rendimiento. El estudio reveló variaciones significativas en los parámetros de crecimiento y rendimiento entre los diferentes tratamientos de fertilizantes. La mayor altura de planta (73.33 cm) a los 45 días después del trasplante se registró en las parcelas tratadas con NPK, que también mostraron el mayor rendimiento de grano (7.04 $t.ha^{-1}$) y un número significativo de granos efectivos por panícula (29.43). Las parcelas con NPK también tuvieron el mayor número de macollos por unidad de área (21.03), mientras que el control tuvo el menor de 12.43.

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Por el contrario, el menor rendimiento de grano (3.51 t.ha^{-1}) se observó en las parcelas testigo, que también registraron la menor altura de planta (47.20 cm) y menor rendimiento de paja (3.97 t.ha^{-1}). Se recomienda encarecidamente la incorporación de Estiércol de Corral torta de semillas oleaginosas de mostaza junto con NPK, ya que esos tratamientos se consideraron excelentes. Si se mezclan con el NPK, el rendimiento podría aumentar, ya que habría interacciones positivas entre ellos.

Palabras clave: *abono, administración, arroz, crecimiento, estiércol, rendimiento*

Introduction

Most of the people all over the world use rice as their main food. In Asia, over 80 % of the population's food security is reliant on rice (Bandumula, 2018). Rice production stepped up drastically between the 1960s and 1980s. The Green Revolution's technological advancements is the primary cause which introduced modern cultivars and boosted the application of mineral fertilizers, irrigation water, and pesticides (Kasim & Hussen, 2019). In rapidly expanding rice growing areas, yield increases are crucial. According to Yuan et al. (2022), approximately 40 % more rice will be needed to meet demand by 2030 without expanding cropping areas.

In the terai region, rice is the primary staple food, contributing significantly to the livelihoods of farm households (Sapkota & Sapkota, 2020). According to Khatri et al. (2023), rice production only satisfies a portion of subsistence farmers' annual food needs. Out of the total food produced in Nepal, the majority is contributed by rice. The productivity of rice, despite being Nepal's leading agricultural crop, lags significantly behind other rice-growing nations with a yield of only 3.5 t.ha^{-1} (Choudhary et al., 2022). 20 % of AGDP is attributed to rice production. 5 130 625 t of rice is produced on 47 % of Nepal's cultivated area, totaling 1 477 378 ha (Ministry of Agriculture & Livestock Development [MoALD], 2024). However, the production and productivity are considered low.

The system of rice intensification was introduced as a strategy for increasing rice yields with fewer external inputs (Adhikari et al., 2018). The system of rice intensification originated from participatory on-farm experiments in Madagascar's central highlands during the 1980s (Uphoff, 2024). The SRI method involves early transplanting of 8-12 days old seedlings, wide spacing of 25 cm x 25 cm or greater, mechanical weeding using a rotary push weeder, water management preventing standing water during growth, and a preference for compost over chemical fertilizers (Bashar et al., 2019).

Rice necessitates the employment of integrated nutrient management encompassing vermicompost, biofertilizers, chemical fertilizers, and organic manure like FYM. Rice growth necessitates the presence of phosphate, potassium, and nitrogen (Trivedi et al., 2018). Wang X. et al. (2020) reported that the combination of organic and inorganic nutrients enhanced soil productivity by improving bacterial community. Vermicomposting maintains soil health and nutrient balance sustainably (Gazi et al., 2024).

Currently, threats in rice cultivation include inefficient use of agro-inputs, declining soil fertility and organic matter, increasing scarcity of water, labor, and other resources, shift in climate, burgeoning cultivation costs, and socioeconomic shifts like urbanization and non-agricultural labor preference (Hou et al., 2020). One of the most crucial production constraints in obtaining a sustainable yield from a specific agricultural technique is nutrient management. An environmentally friendly approach and commercially viable solution to this problem can be achieved by using integrated nutrient management systems where nutrient is supplied to plants to an optimal level through the prudent and effective use of chemical fertilizers, green manure, FYM, and biofertilizers and also preserves the producing characteristics of soil. Applying green manure, FYM, or biofertilizer improves the physical, chemical, and biological properties of the soil, in addition to serving as a supplement.

Nepal's reliance on imports of fertilizer from other nations is hurting commerce (Panta, 2018). Nonetheless, paddy uses the most percentage of all fertilizers sold in Nepal. For sustainable rice cultivation, organic fertilizers can be an additional supply of nutrients (Nayak et al., 2020). It preserves the biological, chemical, and physical fertility of the soil. Sustainable rice production can be sustained by integrating biofertilizers and using a lower dosage of prescribed synthetic fertilizers, thus, ending the reliance on pricey, frequently unavailable synthetic fertilizer. Therefore, a study regarding the efficient fertilizer management practices that improves the growth and yield is necessary. The present study aims to find an efficient fertilizer management practice for maximum grain yield. Outcome of the present study would have practical implications for farmers, which helps them to cultivate rice with best fertilizer use practice.

Materials and methods

The research was performed in southwestern part of the Morang district. It lies at 26.4525° N and 87.2718° E with a total coverage of 58.48 sq. km. The study was carried out from February 2024 to July 2024.

The experiment was performed using a one-factor Randomized Complete Block Design (RCBD) consisting of 7 treatments, which was replicated 3 times. The total area of the experimental field was 136 m^2 with a 1-meter margin between replications. The space between individual plots was 0.5 meters between rows and within rows. The size of the individual plot was kept 4 m^2 (2 m* 2 m) and the spacing of rice plant was kept 25 cm * 25 cm (Bashar et al., 2019). The total plant population was 64 per plot. About 10 %, i.e. 6 plants were tagged for data collection.

Hardinath-1 having 120 maturity days, was used in this research. Inorganic fertilizers such as Urea at 260 $kg.ha^{-1}$, Single Super Phosphate (SSP) at 250 $kg.ha^{-1}$, Muriate of Potash (MOP) at 100 $kg.ha^{-1}$, Recommended Dose of Fertilizer (RDF) at 120:40:50 NPK $kg.ha^{-1}$ and organic sources of nutrients such as Farm Yard Manure (FYM) at 6 $t.ha^{-1}$ with a nutrient content of (N: 0.5 %, P_2O_5: 0.25 %, K_2O: 0.5 %), mustard oilseed cake at 2.5 $t.ha^{-1}$ with a nutrient content of (N: 5 %, P_2O_5: 2 %, K_2O: 1 %), and a control were used as treatments. Weeding was done by hand at 30, 60 and 90 days after transplantation to control weeds. Pretilachlor 50 EC was used as a pre-emergence herbicide, and the required amount of fungicides, insecticides, and bactericides were used uniformly in all plots. Soil analysis was done and the texture of the soil was found loamy with a pH of 6.0. In addition, the soil analysis concluded that the total amount of organic matter, nitrogen, P_2O_5 and K_2O were 1 %, 0.05 %, 25.06 $kg.ha^{-1}$ and 30.25 $kg.ha^{-1}$ respectively.

The treatments, which are also independent variables in the study, are given in the table 1 below.

Table 1. Treatment details

S.N.	Treatments
T1	Nitrogen as urea
T2	Potassium as MOP
T3	Phosphorus as SSP
T4	NPK
T5	Farm Yard Manure
T6	Mustard Oilseed Cake
T7	Control

Treatments were applied in different replications with uniform field management practices (such as irrigation, weeding, disease and pest control) with standard agronomic practices. Following parameters were measured and recorded to evaluate different treatments which are given Table 2.

The data were recorded in MS Excel according to treatments and replications. R- Studio and MS Excel were used for data analysis such as Analysis of Variance and Post Hoc test. The mean values of the treatments were compared to each other based on Duncan's Multiple Range Test (DMRT) at 5 % level of significance.

Results and discussions

Plant Height (cm)

A significant difference between treatments was seen in the height of plants at 30 and 45 DAT. At 30 DAT, plots treated with K i.e. T2 had the tallest plants (50.53), which was also at par with all other treatments. At 45 DAS, the plot with NPK was superior (73.33 cm). However, at both 30 and 45 DAS, the control plot had the shortest height. A similar result was obtained by Shankar et al. (2020), where the plots treated with NPK had the tallest plant than others. Singh et al. (2018) also reported the increment in plant height in plots fertilized with NPK. Regarding

Table 2. Dependent variables

Variable	Assessment method	Frequency/ timing
Plant height (cm)	Measured from the base to the tip of the longest scale by using measuring tape	30 and 45 Days After Transplanting
Number of tillers	Counted manually per tagged plant	30 and 45 Days After Transplanting
Panicle length (cm)	Measured from the base to the tip of the panicle	At maturity
Number of effective tillers	Counted manually per tagged plant and rejected those that did not have panicles	At maturity
1000-grain weight	Harvested the grains from tagged plants and counted 1000 grains and weight was taken	After maturity
Grain yield	Harvested the grains from tagged plants and weight was taken and finally, converted to t ha^{-1}	At maturity
Straw yield	Harvested the grains from tagged plants and weight of straw only was taken and finally, converted to t ha^{-1}	At maturity
Harvest Index	Calculated as: (Grain yield)/(Biomass yield)×100%	After maturity

increment in plant height at 30 DAT, potassium plays an important role in cell expansion in shoot and stomatal regulation, thereby increasing plant height (Sustr et al., 2019) (Table 3).

Table 3. Plant height influenced by different fertilizer management practices at Biratnagar, Nepal

Treatments	30 DAT	45 DAT
Nitrogen as urea	48.67^{ab}	70.17^{a}
Potassium as MOP	50.53^{a}	61.97^{b}
Phosphorus as SSP	44.43^{bc}	49.53^{cd}
NPK	46.30^{abc}	73.33^{a}
FYM	45.53^{abc}	50.67^{cd}
Mustard Oilseed Cake	47.40^{ab}	55.23^{c}
Control	41.53^{c}	47.20^{d}
SEM (±)	1.35	1.62
LSD (0.05)	5.12	6.15
CV (%)	6.21	5.93
Grand Mean	46.34	58.30
F- probability	**	**

*Note: LSD: least significant differences, SEM (±): Standard error of the mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test, and columns represented with the same letter(s) are not significantly different among each other at 5% level of significance. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significant*

Number of tillers

A significant difference was seen in the tiller count. At 30 DAT, the tiller count in a one-meter square of rice field was higher in the plots treated with Nitrogen as Urea (8.20) and NPK (7.60). Likewise, at 45 DAT, the higher tiller count was observed in the plots treated with NPK (21.03) and the lowest was found in the control plots (12.43). A similar finding was concluded by Hoque et al. (2018), where the plots with NPK had one of the the highest number of effective tillers and the control plot had the lowest at farm (Table 4).

Table 4. Number of tillers per unit area influenced by different fertilizer management practices at Biratnagar, Nepal

Treatments	30 DAT	45 DAT
Nitrogen as Urea	8.20^{a}	18.03^{ab}
Potassium as MOP	6.70^{b}	14.07^{cd}
Phosphorus as SSP	6.70^{b}	15.33^{bcd}
NPK	7.60^{ab}	21.03^{a}
Farm Yard Manure	6.73^{b}	16.83^{bc}
Mustard Oilseed Cake	6.93^{b}	15.90^{bcd}
Control	7.07^{b}	12.43^{d}
SEM (±)	0.24	0.99
LSD (0.05)	0.92	3.536
CV (%)	7.27	12.24
Grand mean	7.13	16.23
F probability	*	**

*Note: LSD: least significant differences, SEM (±): Standard error of the mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test, and columns represented with the same letter(s) are not significantly different among each other at 5% level of significance. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significant*

Panicle length (cm)

The mean length of the panicle was 25.59 cm where various fertilizers differ significantly from each other. NPK-treated plots had the longest panicle length (27.80 cm), and the shortest length of panicle (23.53 cm) was seen in the control plot, which was similar in terms of statistics with the Phosphorus and potassium-treated plots. This result matches with the findings of Shankar et al. (2020), where the panicle length was highest in NPK as well, and lowest in the control plot. A similar finding was reported by Apon et al. (2018) where the plot with RDF had one of the longest panicles. These findings coincide with the findings of Lwin et al. (2025). However, the plots treated with nitrogen and the plots treated with mustard seed cake also had longest panicle length. This is due to the fact that nitrogen plays an important role in meristem activity and gibberellin biosynthesis (Souza & Tavares, 2021). Furthermore, the nitrogen demand during the reproductive phase of rice is fulfilled by the mineralization of nitrogen from mustard oilseed cake (Akter et al., 2022) (Table 5).

Table 5. Panicle length number of effective and non- effective tillers per unit area and thousand grain weight influenced by different fertilizer management practices at Biratnagar, Nepal

Treatments	Yield attributing characters		
	Panicle length (cm)	Number of effective tillers	1000 grain weight (g)
Nitrogen as Urea	26.67[ab]	26.37[b]	19.33
Potassium as MOP	24.07[cd]	21.07[d]	18.67
Phosphorus as SSP	25.00[bcd]	23.47[c]	19.33
NPK	27.80[a]	29.43[a]	20.00
Farm Yard Manure	25.73[bc]	27.20[b]	19.33
Mustard Oilseed Cake	26.27[ab]	27.73[ab]	19.33
Control	23.53[d]	17.13[e]	17.33
SEm (±)	0.21	0.24	0.20
LSD (0.05)	1.72	1.95	1.64
CV (%)	3.78	4.45	4.84
Grand mean	25.59	24.63	19.05
F probability	**	***	ns

*Note: LSD: least significant differences, SEM (±): Standard error of mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test and columns represented with same letter(s) are not significantly different among each other at 5% level of significance. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significant*

Number of effective tillers

In terms of statistics, differences were found to exist between different fertilizers on effective tillers count in a hill at a 0.1 % level of significance. The effective tillers count per hill started from 17.13 in the control plot to 29.43 in NPK-treated treatments. The data obtained from plots treated with NPK and mustard oilseed cake are statistically non-significant. The plot with the NPK had a greater number of effective tillers per hill, while the control plot had the least number of effective tillers per hill (Hoque et al. 2018). Furthermore, NPK plays a crucial role in grain filling, root development, and carbohydrate development, thus resulting in an improved number of effective tillers (Du et al. 2021). Similarly, the NPK content in Mustard Seed Cake is comparatively high. This upon mineralization is utilized by rice plants, resulting in a greater number of effective tillers (Table 5).

1000 grain weight (gm)

The overall weight of a thousand grains in the trial was 19.05 g. In terms of statistics, the nutrients did not differ significantly at 0.05 level of significance on test weight. However, between different fertilizers, NPK had the heaviest 1000-grain weight (20.00 grams) and the control plot produced the lightest 1000-grain weight (17.33 grams), while all other data were found to be statistically similar to each other. A similar result was obtained by Hoque et al. (2018) where there were not any significant differences between the treatments which had NPK, FYM and multiple combinations of such treatments. It also agrees with Lwin et al. (2025), where there were not any differences between plots with NPK and a mixture of chemical fertilizers and organic manures (Table 5).

Grain yield (mt/ha)

The overall yield of rice grains in the trial was 4.97 $t.ha^{-1}$. In terms of statistics, differences were found to exist between different fertilizers on yield at a 95 % level of confidence. Yield-attributing parameters such as effective tillers, filled grains per panicle, test weight, panicle length, panicle weight etc. help to increase the final yield of any crop (Pandey et al., 2023). NPK was in the top (7.04 $t.ha^{-1}$) as compared to other treatments in yield of grains. The lower yield was seen in the control plot (3.50 $t.ha^{-1}$). The plots with NPK had the highest yield of rice grains (Hoque et al., 2018). Malo et al. (2018) also reported the highest yield in plots with 100 % RDF. Nitrogen helps in the improvement of assimilation, leaf area production and photosynthetic processes, thus, resulting in improved yield (Fathi, 2022). Phosphorus is important for flower and seed formation (Malhotra et al., 2018). Potassium acts a biofertilizer, thus increasing crop yield. Moreover, it is also crucial for photosynthetic carbon assimilation (Rawat et al., 2022) (Table 6).

Table 6. Grain yield, straw yield and harvest index (%) as influenced by different fertilizer management practices at Biratnagar, Morang 2024

Treatments	Grain yield (t.ha^{-1})	Straw yield (t.ha^{-1})	Harvest Index (%)
Nitrogen as Urea	5.71^{ab}	9.77^{ab}	36.53
Potassium as MOP	3.50^{c}	3.94^{c}	47.25
Phosphorus as SSP	5.67^{ab}	8.98^{ab}	39.35
NPK	7.04^{a}	11.38^{a}	38.54
Farm Yard Manure	4.72^{bc}	8.70^{ab}	36.69
Mustard Oilseed Cake	4.65^{bc}	6.32^{bc}	43.86
Control	3.50^{c}	3.97^{c}	47.25
SEm (±)	0.20	0.46	2.07
LSD (0.05)	1.85	3.79	16.93
CV (%)	18.97	28.09	23.01
Grand mean	4.97	7.59	41.35
F probability	*	*	ns

*Note: LSD: least significant differences, SEM (±): Standard error of the mean, CV: Coefficient of variation, Treatment means separated by Duncan's Multiple Range Test, and columns represented with the same letter(s) are not significantly different among each other at 5% level of significance. *** Significant at 0.001 level of significance, ** Significant at 0.01 level of significance and * Significant at 0.05 level of significant*

Straw yield (mt/ha)

In terms of statistics, differences were found to exist between different fertilizers on the yield of straw at a 95 % level of confidence with a mean straw yield of 7.59 t.ha^{-1}. The maximum straw yield was recorded in NPK-treated plots (11.38 t.ha^{-1}) and the lowest straw yield was observed in the control plot (3.97 t.ha^{-1}). Similar were the findings by Malo et al. (2018). Shankar et al. (2020) reported that the plot with 100% RDF had one of the highest straw yields. Primary essential elements were provided by 100 % RDF for the growth of vegetative parts of plants due to which the highest straw yield was obtained in plots with RDF. However, plots treated with nitrogen, plots treated with phosphorus as well as farm yard manure had higher straw yield. Nitrogen is responsible for the vegetative growth of the plants due to increased photo assimilates, resulting in higher straw yield (Bokado et al., 2020). Phosphorus is important in metabolic and physiological processes of plants, resulting in higher straw yield (Khan et al., 2023). The Farm Yard Manure also had the highest straw yield because it has essential elements such as nitrogen, phosphorus and other elements in required amounts, which is responsible for the vegetative growth. Moreover, the amount of phosphorus in FYM also plays an important role in metabolic and physiological processes of plants, which is responsible for increased straw yield (Table 6).

Harvest Index (%)

The average value index in our trial was 41.35% where there are no significant differences between treatments. The values of the rice harvest index varied greatly among cultivars, locations, seasons, and ecosystems, indicating the importance of this variable for yield simulation (Joshi et al., 2018). Similar was the result obtained by Apon et al. (2018), where no significant differences were seen between treatments in the case of HI (Table 6).

Conclusions

Different nutrient sources were used in rice transplantation to evaluate the yield and yield-attributing parameters. In most of the cases, the treatment with recommended doses of NPK was seen superior as compared to others, especially in the yield and yield attributing parameters. FYM, Oil seed cakes and nitrogen as urea were also seen promising after NPK, which can be seen in the table in each section of the results topic. Hence, to maximize the yield, the application of NPK can be recommended, as it was seen promising in most of the cases. However, the incorporation of FYM and Mustard oilseed cake is also strongly recommended along with NPK, as these manure treatments were also seen outstanding. If they are mixed with the NPK, the yield would potentially be increased as there would be positive interactions between them.

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Conflict of interest

All the authors would like to inform that there is no conflict of interest that could possibly arise in the future.

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Author Contribution

SN: Conceptualization, Methodology, Software, Formal Analysis, Investigation, Resources, Data curation, Writing- Original Draft, Writing-Review & Editing, Visualization, Project administration. **KRG:** Conceptualization, Methodology, Investigation, Resources, Project administration, Visualization, Writing-Review & Editing. **MR & UDB:** Methodology, Investigation, Resources, Project administration. **SK & CS:** Methodology, Investigation, Resources **NB:** Conceptualization, Methodology, Validation, Visualization, Supervision, Project administration. **NK:** Methodology, Investigation, Resources.

ORCID and E-mail

Supriya Niroula	supriyaniraula434@gmail.com
	https://orcid.org/0009-0007-3203-4802
Khem Raj Ghimire	ghimireu13@gmail.com
	https://orcid.org/0009-0009-1097-3758
Melina Rai	melinarai901@gmail.com
	https://orcid.org/0009-0002-3877-6472
Uma Devi Bhandari	umabhandari890@gmail.com
	https://orcid.org/0009-0000-9752-6356
Soniya Koirala	koiralasoniya440@gmail.com
	https://orcid.org/0009-0000-3540-6949
Chandani Sunuwar	chandsu6262@gmail.com
	https://orcid.org/0009-0008-2169-9152
Nabin Bhattarai	nabinbhattaraibhattrai@gmail.com
	https://orcid.org/0009-0007-4553-7900
Nitesh Katuwal	niteshjung16@gmail.com
	https://orcid.org/0009-0009-4144-6918

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