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ASSESSMENTS OF AN INNOVATIVE FERTILIZER MANAGEMENT TOOL (NUTRIENT EXPERT®) FOR IMPROVED NUTRIENT MANAGEMENT OF S*PRING MAIZE* AT RANI JAMARA KULARIYA IRRIGATION COMMAND AREA OF TIKAPUR, KAILALI

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ABSTRACT

A multi-locational field trials were assessed to know the innovative fertilizer management tool (Nutrient Expert®) for improved nutrient management of Spring Maize in Rani Jamara Kulariya Irrigation Project Command Area (RJKIPCA) of Tikapur, Kailali during spring season of 2021. The layout and planting of Spring Maize for NE® - Hybrid Maize model for 42 farmers' fields (Tikapur-18, Janaki-18 and Lamkichuha-6)], and Nutrient Omission Plot Technique (NOPT) maize trials for 21 farmers' fields (Tikapur-9, Janaki-9 and Lamkichuha-3) were grown using baby trail/ diamond trials in Randomized Complete Block Design (RCBD) considering farmers as replications. Data recording, tabulation, and analysis and interpretation of the data was performed by using ANOVA through the use of R Stat-software. Data analysis was also done for the yield gap analysis using percentage change in yield of Spring Maize over the location due to changes in crop cultivars and NOPT. The experimental results highlighted that most of the soils in the project site were deficit in N followed by K, with the minimum yield loss due to omission of P. The treatment; farmers' fertilizer practices (FFP) with their own cultivar has shown more decreasing trend in Spring maize yields and it was more prominently seen within the farmers growing hybrid maize than the open pollinated variety (OPV). With huge percentage of yield gaps in Spring Maize denoted that the soil of Janaki and Tikapur were found to be more prone to N and K nutrients deficient than the soils of Lamkichuha. NE®- Hybrid Maize model has fairly predicted the Spring Maize yields and predicted the sound results on profitability with assured actual attainable yield over the FFP. Therefore, NE-model for Spring Maize is suggested to adopt as a recommended decision support system (DSS) tool in the project command areas of RJKIPCA, Tikapur, Kailali.

Keywords: NE®- Hybrid Maize Model, Productivity, Profitability, NOPT, RJKIPCA, *Spring Maize*

INTRODUCTION

The green revolution in agriculture became successful only after the judicious management of seeds, fertilizers, irrigation water and their scientific management in most of developed world. The government of Nepal (GoN) has also planned to change its subsistence agriculture to commercial and more intensive enterprise-oriented systems for maintaining the balanced human nutrition in sustainable manner as indicated by UN-Sustainable Development Goals (Amgain *et al.,* 2022, MoALD, 2021; Timsina, *et al.,* 2021). Manures and fertilizers being the vital components of the production in any agriculture system, GoN has also given special emphasis on it, but the unavailability of the Urea Nitrogen to be applied on demand at the time of transplanting to heading stages of main season rice, and the same problem with DAP and MOP fertilizers even in spring maize and wheat growing seasons have created the havoc situation, and it is looking a great threat of the country and the agricultural planners and concerned stakeholders are forced to think critically on its alternative remedies.

Fertilizer application decisions in Nepal are different than the green revolutionized world, as it is usually based on perceptions of farmer, which rarely apply balanced nutrition and are often resource driven rather than science driven (Sapkota *et al.,* 2014, Devkota *et al.,* 2016). Further, the government of Nepal has developed National Fertilizer Recommendations for crops which provide a single recommendation for the entire country which is over-simplification of fertilization recommendation and, therefore, is a limitation of the approach (Amgain *et al.,* 2021, Timsina *et al.,* 2021). Under the dominance of marginal and smallholder intensive cropping system growers of Nepal, farmers often over or under use nutrients or apply them in an imbalanced manner, at an inappropriate time, or by wrong methods. Such practices result in low crop productivity and less economic returns and often leave a large environmental footprint of fertilizer use (Timsina *et al.,* 2018, 2021). Hence, the current situation demands nutrient management recommendation guidelines for the farmers that are scientifically robust, user friendly and simple to use (Pampolino *et al.,* 2012). To overcome this issue, the site-specific nutrient management (SSNM) approach based on '4 R' principles i.e., plant need assessment and nutrient application at right time, dose, source and methods (Anand *et al.,* 2017, Bruuleselma *et al.,* 2012, Dobermann *et al.,* 2004) basically suits to the conditions of the majority of Nepalese farmers.

The innovative information and communication technology (ICT)-based decision support systems (DSS) tool principally governed by SSNM principle such as Nutrient Expert (NE®) for Rice, Maize and Wheat developed and evaluated across several farmers' fields in South and South East Asia by the International Plant Nutrition Institute (IPNI), International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Centre (CIMMYT) would be one alternative strategy to overcome the pertinent issues of degraded soil fertility and crop productivity in Nepal (Amgain *et al.,* 2021, IPNI, 2017). Evaluation trials and other studies in Nepal (Amgain et al., 2021, Timsina et al., 2021) and India (Sapkota *et al.,* 2021, Majumdar *et al.,* 2017) have also clearly highlighted the superiority of NE-based nutrient recommendations over farmer's existing practices and state-based recommendations in terms of yield and profitability, as well as for addressing adverse impacts of climate change through mitigation of greenhouse gases emitted from agricultural fields (Bhatta and Aggrawal, 2015). In Jhapa and Morang districts of Far-eastern Nepal, the NE® software has also been found valid to increase the productivity and profitability of rice, maize and wheat (Bogati *et al.,* 2021, Bhatta *et al.,* 2020, Timsina *et al.,* 2021, Amgain *et al.,* 2016).

Rani, Jamara and Kulariya are the three separate farmers managed independent irrigation systems originally constructed by the local *Tharu* peasants of Tikapur, Kailali before 100 years and all these three systems are now integrated to Rani Jamara Kulariya Irrigation System (RJKIS) with the irrigation command areas of about 11,000 ha to the projected command areas of 14,300 ha by 2025 (Annual Report, 2019). At present, the whole agricultural lands of Tikapur municipality and Janaki Rural municipality, and three wards (Byabasthit Nagar (ward # 3), Thapapur (ward # 5) and Hardahani (ward # 7) of Lamkichuha municipality is covered by the RJKIS and three crops a year with high value cash crops are being possible due to the assured irrigation systems available in the channel. Due to the repetitive cultivation of major cereals devoid of legume and scientific crop rotation, and burning of crop residues, the young forest soil of the project site has shown the multi-nutrient deficiency symptoms and recorded the great yield loss in major cereal crops including rice, maize and wheat on recent years (Bist *et al.,* 2021, Annual Report, 2019, Devkota *et al.,* 2016, Pandey *et al.,* 2017). As such, it has also been documented that the soil of the Kailali district is found to be low in soil organic carbon and N, medium in soil available P and K with neutral soil reaction (MoLMAC, 2018).

Maize being the third main food secured crop during S*pring* in all the project sites of Rani Jamara Kulariya Irrigation Project command areas in Kailali (MoALD, 2021, Annual Report, 2020) its productivity has to be raised further to maintain the regional food security status. There are several researches being done and published on the use of NE® crop modelling and found beneficial in economizing the resource use efficiency of major cereals in eastern (Timsina *et al.,* 2021) and hills and Terai of central part (Amgain *et al.,* 2021) of Nepal, but no work or very less work has been initiated in the Far Western Terai region of Nepal, and this research work was planned, executed and accomplished with the objectives to introduce and evaluate the improved nutrient management technologies predicted by the NE® tool together with farmer's current fertilizer management practice in *Spring maize* and to promote the improved fertilizer management technologies to several farmers in irrigation command areas of Rani Jamara Kulariya Irrigation Project for increasing the crop yields, reducing production costs, and increasing farmers income, and thereby contribute to livelihoods.

MATERIALS AND METHODS

Selection of NE®-Modelling and NOPT Research Sites and Questionnaire Survey with Farmers

The geographical maps representing the on-farm research sites for growing NE®-Hybrid Maize and Nutrient Omission Plot Techniques (NOPT) trials of *Spring Maize* at all nine municipal wards of Tikapur Municipality and Janaki Rural Municipality, and selected villages of Ward No. 3, 5 and 7 of Lamkichuha Municipality, where there is access of Rani Jamara Kulariya Irrigation System have been presented in Figure 1.

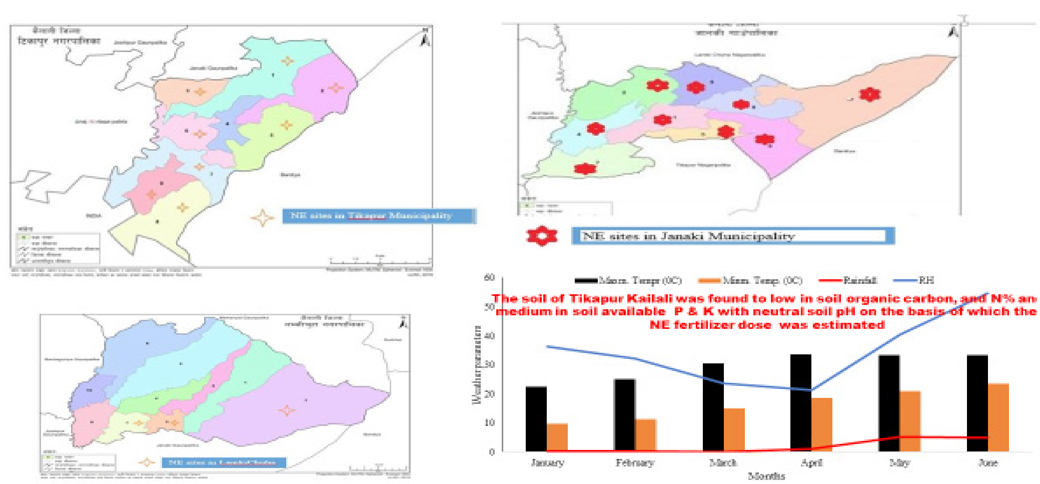

Figure 1. Multi-locational trials on NE®-Maize Model and NOPT experimentations and weather records during crop growing periods (January-June, 2021) for S*pring Maize* at Tikapur and Janaki (all 9 wards) and Lamkichuha (3, 5 & 7 wards) under Rani Jamara Kulariya Irrigation Project Sites

Similarly, the weather record during the experimental crop periods of S*pring Maize* during January to June, 2021 has also been given in Figure 1. While selecting the *Spring Maize* growing farmers, the purposive sampling was followed, wherein, the marginalized, underprivileged, women and co-operative groups were given prioritized. The identification of innovative and progressive farmers were the next criteria in selection of participants in the study. The NE®-Hybrid Maize Model embedded questionnaires was filled by forming a team of faculties, students and staff of the Faculty of Agriculture and Tikapur Multiple Campus for estimation of the NE®-driven fertilizer dose to the 42 *Spring Maize* growers in the irrigation project command areas.

Field experimentations on NE®-Hybrid Maize Model on *Spring Maize*

The improved nutrient management technologies using the NE® tool was evaluated during Feb 15 to March 31, 2021, for S*pring maize* across 42 farmers' fields. While selecting farmers, 21 farmers were given the required seeds of open pollinated variety (OPV) of maize (Rampur Composite) and the remaining 21 farmers were provided the hybrid maize cultivar (Rajkumar). There were four treatments imposed in the study: i) Nutrient Expert®- Hybrid Maize (NE), ii) National Fertilizer Recommendation for hybrid and OPV maize (RD), iii) Farmer's Fertilizer Practices with Scientist's Variety (FFPsv) and, iv) Farmer's Fertilizer Practices with Farmer's Variety (FFPfv) as a dummy check.

The government recommended fertilizer dose for hybrid (150:60:40 kg NPK/ha), and open pollinated maize (120:60:40kg NPK/ha) cultivars were calculated for 50 m^2 area in each farmer's field and were compared for the yield gaps between the FFPsv and FFPfv in each municipal wards of the irrigation command area. The NE® fertilizer recommendation was different as per the farmers for *Spring Maize* growers (Appendices I & II).

Simultaneously, a NOPT trial on S*pring Maize* was conducted in 21 municipal wards of project command area at Tikapur, Janaki and Lamkichuha by using open-pollinated cultivar (Rampur Composite) of maize to diagnose the status of current nutrient status (NPK). All treatments were designed with the concept of Baby trial/ Diamond Trial under RCBD design. The treatments imposed in NOPT trials were i) NPK recommended to *Spring Maize*, ii) Omission of N (-N), iii) Omission of P (-P), and iv) Omission of K (-K). In both NE®- modelling and NOPT trials of S*pring Maize*, the number of farmers were considered the replications. The seeds and fertilizers were provided to all 63 farmers for accomplishing the trials as per the defined treatments mentioned in project. The farmers following the NE®-Maize model and NOPT trials were differed deliberately to reach to the majority number of farmers and to validate the results with maximum number of replications.

Data observations and statistical tools used

Yield attributes of *Spring Maize* were recorded at the harvesting stage of crops as per the standard methods for maize (CIMMYT, 2009). Grain yield of the crop was recorded from the representative sampling areas at least from 25 m^2 area using the scientific techniques of crop cut survey (Reddy and Reddi, 2009). Grain yield and economics of various nutrient management options were compared to demonstrate the productivity and profitability of NE®-based recommendation to the level over the farmers' fertilizer practices. Yield gaps was analysed between the varieties and nutrient management practices from the data of NE® model and NOPT trials. The data on yield and yield responses were recorded and statistical analysis was done using software as per the ANOVA format using R-Stat software as given in Table 1.

Table 1. Statistical design to analyse the data with ANOVA of the S*pring Maize* obtained in NE®- Hybrid Maize Model and NOPT trials of RJKIS during spring season of 2021

SN	Statistical variables	NE®-Maize-Lamkichuha (Factorial RCBD, V = 2, SSNM = 4, Rep = 3)	NE®-Maize-Tikapur & Janaki (Factorial RCBD, V = 2, SSNM = 4, Rep = 9)	NOPT-Maize-Tikapur & Janaki (RCBD, T=4, R = 9)
		V = 2 (Rampur Composite and Raj Kumar hybrid); SSNM = 4 and 3 replications	V = 2 (Rampur Composite and Raj Kumar hybrid); SSNM = 4 and 9 Rep.	SSNM = 4 and 9 replications
1	Replication	2	8	8
2	Treatment			3
3	Variety (V)	1	1	
4	SSNM	3	3	
5	V x SSNM	3	3	
6	Error	14	56	24

RESULTS AND DISCUSSION

Comparisons between the NE® Model predicted and observed yields and net benefit (NRs/ha) over the farmers' fertilizer practices in hybrid and OPV maize cultivars at irrigation command areas of RJKIS

The NE® model predicted yield (attainable yield) and net benefit (NRs/ha) over the farmers' management practices of hybrid (Rajkumar) and OPV (Rampur Composite) maize cultivars along with their yields in farmer's fertilizer practices with the different level of NPK recommendation for different farmers have been presented briefly in Appendices I & II. The validity of the NE®- Maize model was justified by looking the very small variation values within the 10-15% range between the NE® model predicted and observed grain yield and farmer's income (Appendices I-III). As per the survey, the S*pring Maize* is not a priority crop like rice and wheat at the project sites, but the satisfactory yield in the farmer's field due to NE®- Maize treatment was overlooked during the field monitoring and after visualizing the yield records at harvest. It has also shown that the NE® Model treatment showed the extra benefit if farmers really desire to grow the maize as advocated by NE® model treatments. At present, the lack of technical knowledge in making inventory of various production technologies of crops is lacking in Nepal and farmers are getting less profitability from their farming (Amgain *et al.,* 2022; Devkota *et al.,* 2022). The adoption of NE®-Maize model would help the farmers to compare their production and profitability levels in advance in making the cropping system more scientific and technological.

Yield gap analysis in Spring maize under NE-Model and NOPT Trials

The overall mean grain yield of maize obtained from 9 farmers' fields each of Tikapur and Janaki and 3 farmer's field of Lamkichuha recorded that the greater variation in yield of *Spring Maize* was recorded due to omission of N followed by K and P (Table 2).

Table 2. Grain yield and yield gap analysis of maize cultivar (Rampur Composite) grown under NOPT trials at Tikapur, Janaki and Lamkichuha during spring in 2021

Location/ NOPT Treatments	Yield (t /ha)				Yield gaps (t /ha)			% yield gaps		
	NPK	N (-)	P (-)	K (-)	NPK-N	NPK-P	NPK-K	NPK-N	NPK-P	NPK-K
Tikapur (n = 9)	4.52	2.88	3.53	3.83	1.64	0.99	0.70	36.23	34.47	19.74
Janaki (n = 9)	5.77	2.53	4.88	3.69	3.24	0.90	2.08	56.11	35.36	42.64
Lamkichuha (n = 3)	6.53	3.63	5.27	5.51	2.91	1.27	1.02	44.51	34.92	19.41
Mean	5.61	3.01	4.56	4.34	2.60	1.05	1.27	45.62	34.92	27.26

The summary results about the yield gaps of maize due to changes in variety between the farmer's fertilizer practices for the hybrid and OPV maize cultivars grown under the NE- Hybrid Maize trials in all sites of Tikapur, Janaki and Lamkichuha has been presented (Table 3).

Table 3. Summary result on grain yield and yield gaps between farmer's and scientist varieties of maize under their own fertilizer management practices at Tikapur, Janaki and Lamkichuha during spring in 2021

Locations	Maize cultivars	Grain yield of maize (t/ha)		Yield gaps (t/ha)	% yield gaps due to changes in variety
		FFPsv	FFPfv		
Tikapur (n = 18)	Hybrid	7.50	5.65	1.85	22.66
	OPV	4.21	2.88	1.32	27.73
Janaki (n = 18)	Hybrid	7.16	5.57	1.58	24.52
	OPV	5.52	4.45	1.08	19.33
Lamkichuha (n = 6)	Hybrid	3.32	2.66	0.66	18.73
	OPV	3.78	2.64	1.14	30.21

Note: FFPsv = Farmer's fertilizer management practices with scientist given variety and FFPfv = Farmer's fertilizer management practices with farmer's own variety

The results exhibited the significant changes in yield of maize due to change in variety over the farmer's own variety. Maize being a cross pollinated crop, it's seed should be changed over 2-3 years, which was found very rarely practiced within the farmers' level and therefore, recorded the low yield under farmer's fertilizer practices with their own choice of cultivars. The results further exhibited that the yield gaps were higher when farmers adopted hybrid cultivars and it was prominently appeared in Tikapur and Janaki than the Lamkichuha. But, few progressive and innovative farmers of the project sites were found following the practice of growing hybrids in their field as dummy treatments and the grain yield results obtained at their own level of fertilizer management was quite higher especially to the OPV cultivar grown farmers under NE- Hybrid maize trial.

Analysis of yield attributes and yield of S*pring Maize* at RJKIP command areas

Though all data sets are not presented, the major yield parameters of maize like biological yield, number of cobs/ ha area, cob length, kernels / kernel rows, kernels/cob and harvest index of hybrid maize variety at Tikapur was significantly higher than OPV variety, whereas nubbin weight and cob weight of both varieties were statistically at par (Table 4). As similar to cultivar effect, among the four level of SSNM model treatments tested on farmer's field, biological yield, number of cobs/ ha area and kernels/ kernel row were significantly higher on the plot applied with fertilizers dose recommended by Nutrient Expert model. However, some of the yield attributes viz. nubbin weight, cob length and cob weight were statistically at par among all tested models on field. Out of the four tested fertilizer doses, farmer's fertilizer practices with farmer's variety (FFPfv) had recorded lower yield attributes.

Table 4. Major yield attributes [No. cobs/ha and nubbin weight (t/ha)] of hybrid and OPV maize cultivars using NE-Model treatments at Tikapur, Janaki and Lamkichuha during spring season of 2021

Treatments	Tikapur (n = 18)		Janaki (n = 18)		Lamkichuha (n = 6)	
	No. cobs/ ha	Nubbin wt. (t/ha)	No. cobs/ ha	Nubbin wt. (t/ha)	No. cobs/ ha	Nubbin wt. (t/ha)
Due to Cultivars						
OPV	44461.72[b]	1.852[a]	41388.89[b]	1.80[a]	43200.00[a]	2.10[a]
Hybrid	49029.61[a]	2.188[a]	42033.33[a]	2.05[a]	28566.67[b]	1.26[a]
LSD (0.05)	0.780	0.780	0.78	0.78	1.44	1.44
CV (%)	0.0003	8.84	0.003	8.56	0.004	9.22
Due to SSNM practices						
NE	51207.39[a]	2.29[a]	48000.00[a]	2.25[a]	40066.67[a]	1.54[a]
RD	50282.11[b]	2.14[a]	41044.44[b]	1.85[a]	38000.00[b]	1.79[a]
FFPsv	43513.56[c]	1.81[a]	39044.44[c]	1.79[a]	34400.00[c]	1.65[a]
FFPfv	41979.61[d]	1.82[a]	38755.56[d]	1.81[a]	31066.67[d]	1.74[a]
LSD (0.05)	1.104	1.10	1.103	1.10	2.04	2.04
CV (%)	0.003	8.84	0.003	8.56	0.004	9.22

Non-significant differences on yield attributes like nubbin weight, cob weight and kernel rows/cob were obtained among the tested varieties in Janaki. Harvest index of OPV variety (40.56%) was significantly higher than Hybrid variety (33.99%) in the trial (Table 5).

Table 5. Maize kernel yield (t/ha) and harvest index (%) of hybrid and OPV maize cultivars using NE-Model treatments at Tikapur, Janaki and Lamkichuha during spring season of 2021

Treatments	Tikapur (n = 18)		Janaki (n = 18)		Lamkichuha (n = 6)	
	Kernel Yield (t/ha)	Harvest Index (%)	Kernel Yield (t/ha)	Harvest Index (%)	Kernel Yield (t/ha)	Harvest Index (%)
Due to Cultivars						
OPV	4.01[b]	31.09 [b]	5.57[b]	40.56[a]	3.97[a]	24.92[a]
Hybrid	7.95[a]	43.32 [a]	7.14[a]	33.99[b]	3.79[a]	25.88[a]
LSD (0.05)	0.780	0.780	0.78	0.78	1.44	1.44
CV (%)	17.63	4.44	15.98	4.43	12.59	6.51
Due to SSNM practices						
NE	7.19[a]	36.56[b]	7.38[a]	35.96[c]	5.07[a]	27.92 [a]
RD	6.62 [ab]	39.05[a]	6.70[ab]	37.81[b]	4.25[ab]	26.64[a]
FFPsv	5.83 [b]	39.02[a]	6.23[b]	39.81[a]	3.55 [ab]	26.21[a]
FFPfv	4.28 [c]	34.22[c]	5.11[c]	35.52[c]	2.65[b]	20.82[b]
LSD (0.05)	1.10	1.10	1.10	1.10	2.04	2.04
CV (%)	17.63	4.44	15.98	4.43	12.59	6.51

Among the four tested SSNM models in the experiment, higher number of cobs/ ha (48000) and kernels/ kernel row (29.58) was obtained from the plot subjected with Nutrient Expert model recommended fertilizers dose than other treatments. Non-significant differences result was also observed on nubbin yield, cob length, cob weight, kernel rows/ cob among tested models in the experiment of Janaki. In the experiment conducted in Lamkichuha Municipality of Kailali district, OPV and Hybrid variety had exhibited statistically higher cob yield (6.51 t/ha) and number of cobs/ ha area (43200) than hybrid variety (5.06 t/ha) tested. Apart from these, all other attributes (nubbin weight, biological yield, harvest index, cob length, cob weight, kernel rows/ cob, kernels/kernel row) were statistically at par among the tested varieties (Table 4 and 5). Of the four tested SSNM model treatments (Nutrient Expert model, recommended dose, Farmer's fertilizer practices with scientist variety, farmer's fertilizer practices with farmer's variety), the Nutrient Expert model recommended dose of fertilizers resulted the significantly higher number of cobs/ ha area (40066.67) than all other tested models in farmers' field. Nubbin weight, cob length and cob weight among all the tested treatments in the experiment was statistically at par. Farmer's fertilizer practice with farmer's variety of maize had lower yield along with most of the yield attributes (Table 5). Of the two maize cultivars tested on different four level of SSNM treatments at farmer's field of Tikapur and Lamkichuha Municipalities and Janaki Rural Municipality in Kailali district, hybrid cultivar showed significantly higher kernel yield (7.95 t/ha) than OPV cultivar (4.01 t/ha) at Tikapur. As similar to cultivar, SSNM model treatments tested at farmer's field, kernel yield (7.19 t/ha) was significantly higher on the plot applied with fertilizer dose recommended by NE®- Hybrid Maize model at Tikapur (Table 5). The findings are in accordance with the findings of Dahal et al. (2014) at Rampur, Chitwan and Khanal *et al.* (2017) at Gauradah and Damak in Jhapa districts of Nepal.

Similarly, cob yield (9.20 t/ha) and kernel yield (7.14 t/ha) of hybrid cultivar recorded significantly higher yield over OPV cultivar grown in the study at Janaki. Amongst the four tested SSNM fertilizer treatments in the experiment, higher cob yield (9.64 t/ha), and kernel yield (7.38 t/ha) were obtained from the plot subjected with NE®- Hybrid Maize model recommended fertilizer dose than other models in Janaki. In the experiment conducted at Lamkichuha Municipality in Kailali district, OPV and Hybrid cultivars had exhibited non-significant difference on kernel yield, whereas OPV had significantly higher cob yield (6.51 t/ha) than hybrid cultivar (5.06 t/ha) tested. Of the four tested SSNM models (NE®- Hybrid Maize model, recommended dose, Farmer's fertilizer practices with scientist variety, farmer's fertilizer practices with farmer's variety), the NE®- Hybrid Maize model recommended dose of fertilizer resulted the significantly higher cob yield (6.90 t/ha) and kernel yield (5.07 t/ha) than all other tested SSNM fertilizer doses in farmers' field (Table 5).

The cursory view on the yield of *spring maize* cultivars grown under nutrient omission plot techniques (NOPT) in Tikapur and Lamkichuha Municipalities and Janaki Rural Municipality of Kailali district is presented in Table 6. The result mentioned that maize kernel yield was found significantly higher on NPK treated plot (4.22 t/ha) over the N and P omission plots, while these both are statistically at par in Tikapur. The minimum kernel yield was obtained from the (–N) treated plot (2.88 t/ha). Similarly, the kernel yields of spring maize in Janaki municipality was significantly higher on NPK treated plots (5.77 t/ha) than the N and P omission treatments which were statistically at par with K omission plot (4.88 t/ha). The balanced fertilizer dose available from the very beginning of the crop emergence under NPK plot resulted the proper germination, crop vigour and optimum plant population and, therefore resulted the higher number of cobs/ ha, kernels/ kernel row and 1000-kernel weight which ultimately increase the kernel yield (Amgain et al. 2021, 2016).

Table 6. Yield and yield responses of maize cultivars under nutrient omission plot techniques (NOPT) trials at RJKIP command areas of Tikapur during spring season in 2021

Treatments	Tikapur (n = 9)	Janaki (n = 9)	Lamkichuha (n = 3)
NPK	4.42[a]	5.77[a]	6.34
N (-)	2.88[b]	2.53[c]	3.62
P (-)	3.72[ab]	3.69[b]	5.28
K (-)	3.92a	4.88[a]	5.68
LSD (0.05)	0.95	0.99	NS
CV (%)	16.05	14.02	14.69

The sporadic fertility status of the soil of RJKIP command areas have shown that the soil is mostly deficient in N causing low yield of cereal crops as mentioned by Amgain *et al.,* 2021, 2016; Gautam *et al.,* 2018 in Terai region of Eastern Nepal. The N omission (-N) recorded significantly lowest values of various yield attributes over P and K omissions. Potassium is the nutrient for maintaining the catalytic role of the N and P, therefore, the K omission plots showed the maximum attack of major pest and diseases and resulted lower yield and yield attributes as corroborated with the findings of Timsina *et al.* (2010). The sporadic fertility status of the soil of RJKIP command areas has shown that the soil is mostly deficient in N causing low yield of cereal crops. The soil inventory map of Kailali district prepared and published by Ministry of Agriculture, Soil Science Directorate has also shown the very less N and SOC and medium level of P and K status in the surface soil of Kailali (MoLMAC, 2018).

CONCLUSION

NE®- Hybrid Maize model have fairly predicted the *Spring Maize* yields and predicted the satisfactory economics with sound profitability after assuring the steadily increasing level of actual attainable yield over the farmer's fertilizer practice. Hence, the adoption of NE®- Hybrid Maize model is suggested to adopt as a sound decision support system (DSS) tool to manage the soil fertility and crop productivity in the project command areas of RJKIP at Tikapur, Kailali. Under the prevailing conditions, it is highly expected that there would be spill-over effects of this project activity to the nearby areas of Tikapur, and the NE® tool could potentially be used by national, provincial, agriculture knowledge centre and village-level stakeholders to provide fertilizer recommendations to many other farmers' field from Kailali to Kanchanpur and Bardiya to Banke districts; all the bread basket pockets of food grain crops. However, it is suggested that for more valid and reliable conclusion, the multi-locational trials at least for 2-3 years would be continued with increasing number of farmers.

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Appendix-I. NE®- Hybrid maize model predicted grain yield, recommended fertilizer dose and economics of OPV maize cultivar at Tikapur, Janaki & Lamkichuha municipalities under RJKIP command areas during spring in 2021

Villages/ Wards	NE predicted yield (t/ha)		Observed yield (t/ha)		NE predicted NPK (kg/ha)			NE projected Benefit (NRs/ha) over FFPfv
	FFPfv Survey	NE Predicted	FFPfv Obs.	NE Observed	N	P	K	
OPV Maize Tikapur								
Chhegarkhaila, 1	1.5	4	1.47	2.19	120	24	21	55372
Bandipur, 2	2.4	5	3.47	3.65	110	27	33	27850
Rampur, 3	2.25	3	3.53	5.07	90	20	26	35759
Baghmara, 4	2.1	4	2.43	7.62	100	24	29	61986
New Tikapur, 5	3.0	6	3.23	3.55	120	30	46	47907
Ambasa, 6	1.5	4	1.72	1.93	100	24	29	58324
Shatti Padampur, 7	1.4	4	2.65	4.17	120	24	36	77678
Karmidanda, 8	2.8	6	4.95	6.73	100	30	46	69606
Karmidanda/ Jhunga, 9	1.8	4	2.74	4.44	130	33	41	69493
OPV Maize Janaki								
Dharmapur, 1	2.14	5	5.46	7.62	110	27	33	89450
Paragipur, 2	2.3	5	5.69	7.10	110	27	33	99056
Bhagatpur, 3	1.75	5	4.78	7.84	110	27	33	97508
Kanchanpur, 4	1.2	4	2.78	5.19	100	24	29	95138
Amauri, 5	2.32	5	4.30	5.18	110	27	33	34530
Jagatpur, 6	2.4	5	6.41	7.04	100	33	51	46330
Tikuligadh, 7	1.2	4	2.01	4.19	130	27	41	53757
Jawalpur, 8	1.15	4	3.55	3.86	100	24	29	51950
Khairiphanta, 9	1.15	6	3.65	6.97	120	30	37	64450
OPV Maize Lamkichuha								
Byabasthit Nagar, 3	1.2	4	2.14	3.43	90	24	21	23200
Thapapur, 5	2.5	6	2.84	6.04	120	34	36	34990
Hardahani, 7	2.2	4	3.95	6.43	120	24	29	26713

Appendix-II. NE®- Hybrid maize model predicted grain yield, recommended fertilizer dose and economics of hybrid maize cultivar at Tikapur, Janaki & Lamkichuha municipalities under RJKIP command areas during spring in 2021

Village/ Ward	NE-Yield (t/ha)		Observed Yield (t/ha)		NE-NPK (kg/ha)			Benefit (NRs/ha) over FFPfv
	FFPfv Survey	NE Predicted	FFPfv Obs.	NE Observed	N	P	K	
Hybrid Maize Tikapur								
Bangaoun, 1	3.0	6	3.95	6.50	110	37	33	91100
Seetapur, 2	3.0	5	4.47	8.28	130	27	33	64918
Rampur, 3	1.25	4	2.96	5.59	100	24	14	73796
Baghmara, 4	1.4	4	6.05	8.04	100	24	29	29620
Pahadipur, 5	1.9	5	4.39	9.62	120	30	37	126587
Narayanpur/ Bandraiya, 6	2.2	6	6.24	8.56	120	30	46	72058
Bharthapur, 7	1.5	5	5.70	9.61	130	33	51	46906
Shatti Bangaun, 8	1.6	5	6.31	9.10	130	27	41	41326
Jhunga, 9	2.4	5	4.79	10.78	110	27	41	65400
Hybrid Maize Janaki								
Dharmapur, 1	2.1	5	6.52	8.24	110	27	41	83605
Kalikapur, 2	2.3	5	7.30	9.23	110	27	33	67768
Subarnapur, 3	3.1	7	5.31	4.75	130	33	51	14227
Munuwa, 4	1.6	5	1.34	6.36	110	27	33	19773
Amaura, 5	2.7	8	5.04	7.90	130	33	51	35029
Dharmapur Katan, 6	2.5	7	2.61	7.13	130	33	40	75831
Motinagar, 7	2.4	7	7.01	9.73	130	33	51	59208
Jabalpur, 8	3.0	5	6.49	7.08	110	27	33	7663
Khairaphanta, 9	2.0	4	5.18	9.55	100	24	21	42324
Hybrid Maize Lamkichuha								
Baybasthit Nagar, 3	2.3	5	3.95	5.38	90	27	41	81881
Thapapur, 5	1.1	4	1.51	4.33	90	27	41	18050
Hardahani, 7	2.5	6	2.52	4.85	100	30	37	64857