



Deep Placement of Briquette Urea Increases Agronomic and Economic Efficiency of Maize in Sandy Loam Soil

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ABSTRACT

Imbalanced use of fertilizers along with inappropriate sources and application methods has attributed to reduced nitrogen use efficiency (NUE) and crop productivity. The use of the right N source and appropriate application method is essential to reduce N losses and increase NUE, crop yield, and economic return. A field trial was conducted at the Agricultural Research Station, Dasharathpur, Surkhet following a randomized complete block design with seven treatments (three replications) using various N sources (urea, urea briquette, and three different blended fertilizers) and their application methods to assess their fertilizing efficiencies. Treatments showed a significant effect ($p < 0.05$) for all the traits viz. plant and ear height, stover and grain yield, harvest index, and thousand-grain weight. Compared to the recommended dose of fertilizer (RDF), the grain yield advantage of blended fertilizer (10:26:26 NPK) in a combination of Zinc followed by RDF+Zn and urea deep placement (UDP) applied treatments were 7.8, 2.7, and 2.4% respectively. Among all, deep placement of urea briquette was found to be economic for the cultivation of Khumal Hybrid-2 maize variety while producing similar yield (2.4% higher) with 25% lower nitrogen dose, increasing agronomic nitrogen use efficiency by 10.41 kg/kg N, and economic benefit by US\$30.4/ha compared to RDF.

INTRODUCTION

Maize is a staple crop after rice and contributes significantly to national food security in Nepal (MoALD, 2020). It is grown widely across different agro-ecological zones, as a rainfed crop in Hills, and under irrigation during spring and winter in Terai and Inner-Terai regions of Nepal. Maize is cultivated in a total of 0.96 million ha area with a production of 2.71 million tons, and average productivity of 2.84 t/ha (MoALD, 2020). However, with increasing demand, especially for poultry industries, national production is not sufficient, and therefore, the country imports maize in large quantities every year (KC, Karki, Shrestha, &

Achhami, 2015; Osti, 2019; TEPC, 2019). Though various improved and hybrid maize varieties have been released, registered, and cultivated (MoALD, 2020; SQCC, 2019), maize productivity is still low compared to other South Asian countries (FAOSTAT, 2020). One of the reasons of low productivity is poor management of soil fertility. Improving soil fertility management could increase yield and reduce the yield gap of both hybrid and improved varieties (KC, Karki, Shrestha, & Achhami, 2015; Paudyal et al., 2001). Nepal Agricultural Research Council's recommendations for maize are 120:60:40 kg N:P₂O₅:K₂O/ha. However, fertilizer use by farmers is usually low as the supply of fertilizers at key times, and knowledge regarding their use is poor

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(Adhikari, Timsina, Brown, Ghimire, & Lamichhane, 2018; KC, Karki, Shrestha, & Achhami, 2015). Even if recommended doses were applied, the yield gap in hybrid and improved varieties were still higher as these recommendations were made decades ago and they are not yet updated to fulfill the nutrient requirement of recently developed varieties including hybrids (KC, Karki, Shrestha, & Achhami, 2015; MoALD, 2020). These facts strongly suggest the need for improved fertilizer recommendation for specific ecological belts and growing seasons.

Fertilizers are critical components of the production system for supplying nutrients that are essential for the proper growth and development of crops. Farmer's practice of fertilizer use in Nepal is low and imbalanced. Nutrient loss from most commonly used nitrogenous fertilizer such as urea) is very high. The losses are associated with inefficient application methods such as broadcasting and wrong timing of application as farmers' awareness of N management is poor. The nutrient loss not only contributes to low fertilizer use efficiency, but also contributes to climate change, eutrophication, and biodiversity degradation (Conijn, Bindraban, Schröder, & Jongschaap, 2018; Fugice, Dimkpa, & Johnson, 2018). Among the essential nutrients, nitrogen is the most limiting nutrient for crop production. However, almost half of the applied nitrogen could be lost to the atmosphere which adds to atmospheric greenhouse gas emission, pollution of both underground as well as surface water (Fugice, Dimkpa, & Johnson, 2018). In addition, a higher amount of urea application increases soil acidity for years, thereby adversely affecting the physical and chemical properties of soil (Lungu & Dynoodt, 2008). Due to these reasons, research and improvements have been mostly made on nitrogen-based fertilizers focusing on slow or controlled release fertilizers (Fugice, Dimkpa, & Johnson, 2018).

In Nepal, the most commonly used fertilizers are urea, Diammonium phosphate (DAP) and murate of potash (MOP), and the sales from 2010 to 2016 show an increasing trend by 141%, 421.80%, and 183.23%, respectively. In addition, these fertilizers are also sold by the private sector and farmers also buy them from the gray market. The use of urea alone is double that of DAP, while the use of MOP is very low for major cereal crops (MoALD, 2018). The nutrient loss could be minimized if fertilizers are applied following 4R's of nutrient stewardship (right

source, right rate, right time, and right placement) approach, which could make fertilizer use more economic, environmentally sound and socially just (TFI, n.d.). Additionally, innovative fertilizers and application technologies are being developed and tested in different countries for validating their effectiveness in reducing nitrogen losses and increasing fertilizer use efficiency. Innovative fertilizers include different coated (either organic or inorganic) fertilizer such as polymer or sulfur, nitrification inhibitors, urea briquette, etc (Bindraban et al., 2020; Fugice, Dimkpa, & Johnson, 2018). These fertilizers can be applied as a single dose during planting time and release nutrients slowly to provide season-long requirement of crops thereby reducing additional labor of top dressings (Choudhary et al., 2016; Liu et al., 2014).

Several studies reported the effectiveness of innovative fertilizers and application technologies. They are more efficient over granular or prilled urea and its conventional broadcast application method. Higher agronomic nitrogen use efficiency of maize at 90-135 kg N/ha (25.8- 47.31 kg grain per kg applied N) was observed from UDP compared to the conventional broadcast application at 90-135 kg N/ha (Agyin-Birikorang et al., 2020; Jiang, Lu, Zu, Zhou, & Wang, 2018; Jiang et al., 2019). Likewise, higher efficiency and effectiveness of UDP in reducing nitrogen loss and yield increment was also reported by researchers from China and the USA (Halvorson & Del Grosso, 2013; Jiang, Lu, Zu, Zhou, & Wang, 2018; Jiang et al., 2019). However, studies on the effects of UDP in maize yields and NUE in Nepal are still limited.

Moreover, the crop requires balanced fertilization for optimum growth and yield. One of the alternatives of balanced fertilization is the use of blended fertilizers that provide deficient plant nutrients (both macro and micro nutrients) as per site and crop demand (Sitienei, Kamiri, Nduru, & Kamau, 2018b). Farmers of Nepal commonly apply Urea, DAP, and MOP fertilizers to supply major nutrients to crops. Among the three fertilizers, farmers prefer urea compared to MOP leading to an imbalanced supply of nutrients to crops. Blended fertilizers were reported to be effective for increasing yield and maintaining soil fertility status (Chimdessa, 2016; Njoroge, Otinga, Okalebo, Pepela, & Merckx, 2018; Sitienei, Kamiri, Nduru, & Kamau, 2018a) as they may supply both macro and micronutrients to crops. However, studies on blended fertilizers comparing

with the straight fertilizers are yet to be conducted in Nepal.

Therefore, this study was conducted to investigate the effects of deep placement of briquette urea and blended fertilizers on grain yield, nutrient use efficiency and economic returns of maize comparing with government recommended rates in Mid- western river basin of Nepal.

MATERIALS AND METHODS

Experimental Site

A field experiment was conducted at Agriculture Research Station, Dasharathpur, Surkhet, Nepal (28° 30' northern latitude, 81° 47' eastern longitude, and 490 meters above mean sea level) from June to September 2019. The experimental site recorded an average rainfall of 169.3 mm during the study period. The average monthly rainfall was highest in July (236.5 mm) followed by June (245.8 mm) and August (186.6 mm). The average minimum and maximum temperatures during the study period were 22.5 and 35.1°C, respectively. June was the hottest month (36.7°C) followed by August (34.7°C).

Soil samples were collected randomly from a depth of 0-20 cm representing the overall study area and were analyzed following standard procedure in the chemistry laboratory of Soil Science Division, Khumaltar, Lalitpur. Soil analysis report indicated that soil was sandy loam with pH 6.11 (slightly acidic), organic matter 1.87% (medium), total nitrogen 0.09% (medium), phosphorus 30.57 mg/

kg (medium), and potassium 104.50 mg/kg (low), respectively.

Experimental Setup

Seven fertilizer treatments (Table 1) were deployed in a randomized complete block design with three replications. Replications were one meter apart, and each plot was 0.5 meters. The size of each treatment plot was 25 m² (5 m × 5 m) comprising 6 lines each with 20 plants at a distance of 75 cm and 25 cm between rows, and plants, respectively. Two seeds per hill were sown 5-7 cm below the soil surface which was later maintained as a single stand by thinning at 25 days after sowing. During field preparation, deep ploughing was performed twice followed by harrowing, and levelling. For each treatment plot, the fertilizer amount per plant was calculated and applied in rows at depth of 5-7 cm at a similar distance. Urea was top-dressed in two equal splits at six (V6) and ten leaf stage (V10) in the respective treatments. Urea briquettes (a compressed form of urea, 46% N) were applied at the V6 stage in the depth of 5-7 cm and 5-7 cm distance from plants. The average size of each briquette was 2.7 g and a single briquette per plant was applied. Blended fertilizers, DAP (18% N and 46% P₂O₅), MOP (60% K₂O), and micronutrient (Zn) were applied once (single application) during planting. The remaining amount of nitrogen for fertilizer blend treatments (T5, T6, and T7) were top-dressed during V6 and V10 stages with conventional urea.

Table 1. Detail about different treatments with various N sources used in the study

Treatments	Abbreviations	Details
T1	CK	Control
T2	RDF + Zn	120:60:40 NPK kg/ha + 20 kg/ha ZnSO ₄
T3	RDF	120:60:40 NPK kg/ha
T4	UDP	90:60:40 kg NPK /ha + 20 kg ZnSO ₄
T5	Comp- 1	NPK 12-32-16 applied at 120:60:30 kg NPK/ha + 20 kg ZnSO ₄
T6	Comp- 2	NPK 10-26-26 applied at 120:60:60 kg NPK/ha + 20 kg ZnSO ₄
T7	Comp- 3	NPK 20-20-10 applied at 120:60:30 kg NPK/ha + 20 kg ZnSO ₄

Remarks: RDF: government recommended dose of fertilizers for maize (KC, Karki, Shrestha, & Achhami, 2015); CK: no fertilizer and manure application; UDP: urea deep placement; Comp- 1, Comp- 2, Comp- 3: three different blended fertilizers

Crop Management

Khumal Hybrid- 2 maize variety was used for the experiment which was released by the Nepal Agricultural Research Council (NARC) in the year 2014 with a yield potential of 9.02 t/ha and 8.5 t/ha in Mid Hill and Terai, respectively (SQCC, 2019). The experimental site was cropped with wheat during the previous season. The seeds were sown on June 6, 2019, and cultivated under the rainfed condition and were harvested on September 16, 2019. Other agronomic management practices such as weeding and pest and disease management were performed as required following standard protocols from NARC.

Recording of Yield, Yield Components and Nitrogen Use Efficiency

Plant and ear heights were recorded based on observation of 5 sample plants from the central two rows of the plots. Harvesting was performed manually by cutting plants from 5 cm above the ground level; 2 m length from two central rows (2 m × 1.5 m = 3 m²) excluding at least 4-5 outer plants of the lines in both the sides. Immediately after harvesting, cobs were removed from stover to record stover yield per plot followed by removal of outer husk cover to record fresh cob yield per plot. Grain moisture content was recorded using a digital moisture meter. From dried cobs, 300 grains were counted and weighed to express thousand-grain weight. Conversion of cob and stover yield per plot to yield per hectare, calculation of harvest index, partial factor productivity (PFPN), and agronomic use efficiency (AEN) of nitrogen were performed using following formulas.

$$\text{Grain yield } \left(\frac{\text{kg}}{\text{ha}}\right) = \frac{\text{Plot yield (kg)}}{\text{Net harvested area}} \times \frac{(100 - \text{recorded moisture})}{(100 - \text{adjusted moisture})} \times 0.8 \times 10000. \quad 1)$$

$$\text{Stover yield } \left(\frac{\text{kg}}{\text{ha}}\right) = \frac{\text{Plot yield (kg)}}{\text{Net harvested area}} \times 10000. \quad 2)$$

$$\text{Harvest Index (HI)} = \frac{\text{Grain Yield (kg/ha)}}{\text{grain yield (kg/ha)} + \text{stover yield (kg/ha)}}. \quad 3)$$

$$\text{Agronomic Nitrogen Use Efficiency (AEN)} = \frac{Y_t - Y_o}{N_a}. \quad 4)$$

Where, Y_t = Grain yield in the test treatment (kg/ha), Y_o = Grain yield in the control plot (kg/ha), N_a = N applied to the test treatment (kg/ha). Grain moisture was adjusted to 12%, shelling percentage taken as 80% (Badu-Apraku, Fakorede, Menkir, & Sanogo, 2012), the biological yield was estimated by adding grain and stover yield.

$$\text{Partial Factor Productivity (PFPN)} = \frac{\text{Grain yield (kg/ha)}}{\text{amount of N applied (kg/ha)}}. \quad 5)$$

Economic Analysis

The economic analysis was conducted based on partial budgeting of different treatments considering variable cost related to fertilizer application referring methods of Badu-Apraku, Fakorede, Menkir, & Sanogo (2012). Quantity of maize threshing using hand sheller was used as suggested by Amare et al. (2017). Prices of inputs, labor, grain and crop residues (stover, husk) were fixed based on the local market (Birendranagar and Dasharathpur, Surkhet) survey. B:C ratio was calculated using the following formula.

$$\frac{B}{C} \text{ ratio} = \frac{\text{Total revenue}}{\text{Total cost of cultivation}}. \quad 6)$$

Data Analysis

AEN and PFPN were calculated as suggested by Fixen et al. (2014). Data analysis was performed using Microsoft excel 2007, and Crop Stat 7.2. One-way ANOVA followed by Fisher LSD (0.05) test was performed for mean comparisons.

RESULTS AND DISCUSSION

Yield Attributing Characters

Treatments had significant effects on plant, and ear height, grain and stover yield, harvest index and thousand-grain weight (Table 2). Despite a lower dose of nitrogen (90 kg/ha), urea briquette treatment (deep placement method) produced the tallest plant height (279.67 cm), and ear height (162.93 cm). This might be due to increased nitrogen uptake, and reduced nitrogen losses (ammonia volatilization, emissions of nitrous oxide) from deep placed urea briquette (Halvorson & Del Grosso, 2013). In accord to present findings, the effectiveness of the deep placement methods for improving agronomic traits was also reported by (Liu et al., 2019). The highest stover yield and thousand-grain weight were recorded for RDF (120:60:40 NPK kg/ha), whereas treatment with blended fertilizers (10:26:26 NPK) in combination with micronutrient Zn produced the highest harvest index (Table 2). In accordance with this, Chimdessa (2016) reported higher harvest index (0.48- 0.50) on maize with the use of blended fertilizers. Increase in thousand grain weight, harvest index, and stover yield in response to increased nitrogen doses were reported in maize hybrids in the Nepalese condition (Dawadi & Sah, 2012; Sapkota, Shrestha, & Chalise, 2017).

Table 2. Effect of different fertilizer treatments on the agronomic, and yield components of Khumal Hybrid-2 variety of Maize

Treatment	PH (cm)	EH (cm)	STOY (t/ha)	HI	TGW (gram)
CK	237.067 ^d	130.133 ^c	12.022 ^c	0.241 ^d	290.556 ^b
RDF+Zn	276.533 ^a	161.133 ^a	18.944 ^b	0.272 ^{bc}	343.222 ^a
RDF	269.867 ^{ab}	153.4 ^{ab}	21.344 ^a	0.246 ^{cd}	358.778 ^a
UDP	279.667 ^a	162.933 ^a	18.488 ^b	0.277 ^{ab}	350.222 ^a
Comp- 1	254.267 ^c	143.067 ^b	16.955 ^b	0.276 ^{ab}	342.222 ^a
Comp- 2	269.6 ^{ab}	148 ^b	17.166 ^b	0.302 ^a	345.778 ^a
Comp- 3	259.267 ^{bc}	143.733 ^b	16.966 ^b	0.291 ^{ab}	344.556 ^a
Grand mean	263.75	148.91	17.413	0.272	339.33
F-test	**	**	**	**	**
SEM	4.56	3.692	0.752	0.009	8.017
CV (%)	3	4.3	7.5	5.8	4.1
LSD (0.05)	14.04	11.375	2.319	0.028	24.703

Remarks: CK: no fertilizer and manure application; RDF: recommended dose of fertilizer; UDP: urea deep placement; Comp- 1, Comp- 2, Comp- 3: three different type of compound (blended) fertilizers; PH: plant height, EH: ear height, STOY: stover yield, HI: harvest index, TGW: thousand grain weight; * significant at 5% level of significance, ** significant at 1% level of significance, CV: Coefficient of variation, LSD: least significant difference, SEM: standard error of mean. Values in a column having common letters do not differ significantly at 5% level of significance

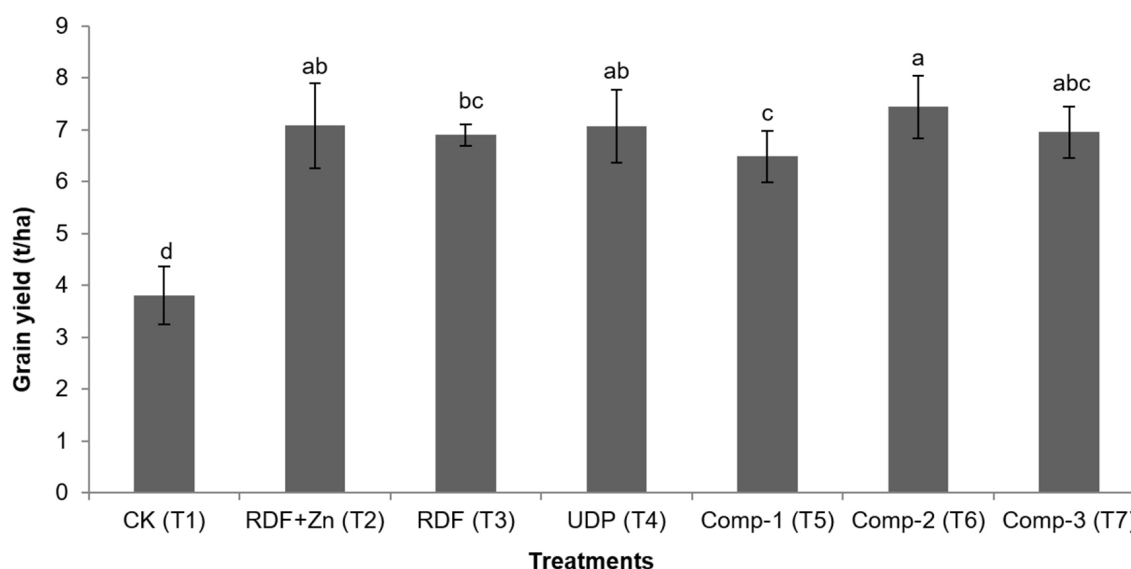
Grain Yield

All treatments with various N sources and application methods showed significantly higher grain yield compared with control. Fertilized treatments produced grain yield in the range of 6.48-7.43 t/ha. Among the treatments, the highest grain yield was observed for blended fertilizer (10:26:26 NPK) in combination with Zn followed by RDF+Zn and UDP (Fig. 1). Blended fertilizer produced 7.8 % more grain yield in comparison to RDF, which is most possibly due to a balanced supply of nutrients to the crop. As the soil of the experimental site was low in potassium, the use of blended fertilizer with 120:60:60 kg NPK/ha added K into the soil which might have a positive influence on grain yield despite applying similar N and P fertilizers in all treatments. As reported by Sangakkara, Amarasekera, & Stamp (2011) integrated use of potassium with N fertilizers could enhance crop productivity. Researchers reported blended fertilizers in combination with micronutrients were effective for increasing maize yield (Chimdessa, 2016; Njoroge, Otinga, Okalebo, Pepela, & Merckx, 2018).

Urea briquette with a 25% lower N rate (90 kg/ha) produced 2.4% more grain yield compared to RDF (120 kg N/ha, without Zn). This might be due to the reduction of N losses due to deep placement

technology, that retains nitrogen in the root zone for a prolonged period and release slowly based on the physiological requirement of the crop (Halvorson & Del Grosso, 2013; Jiang, Lu, Zu, Zhou, & Wang, 2018). This result implies the importance of the deep placement of urea briquette in reducing N losses compared to the conventional broadcast application of urea at multiple splits. Most previous studies reported the effectiveness of urea deep placement technology over traditional broadcasting of urea on increasing maize yield (Agyin-Birikorang *et al.*, 2020; Halvorson & Del Grosso, 2013; Jiang, Lu, Zu, Zhou, & Wang, 2018; Jiang *et al.*, 2019; Johnson II, Nelson, & Motavalli, 2017; Liu *et al.*, 2019). This study suggested that UDP could reduce nitrogen input by 25% while producing similar yields compared to RDF.

The addition of micronutrient Zn in RDF treatment increased grain yield by 2.66% compared to RDF without Zn, highlighting the importance of Zn addition on crop yield (Fig. 1). Several researchers (Kugbe, Kombat, & Atakora, 2019; Ruffo, Olson, & Daverede, 2016; Sahrawat, Rego, Wani, & Pardhasaradhi, 2008), reported that zinc increases yield and grain quality of maize when used in combination with major nutrient elements.



Remarks: CK: no fertilizer and manure application; RDF: recommended dose of fertilizer; UDP: urea deep placement; Comp- 1, Comp- 2, Comp- 3: three different type of compound (blended) fertilizers

Fig. 1. Grain yield of maize (Khumal Hybrid- 2) produced by the effect of different fertilizer treatments

Partial Factor Productivity (PFPN) and Agronomic Use Efficiency (AEN) of Nitrogen

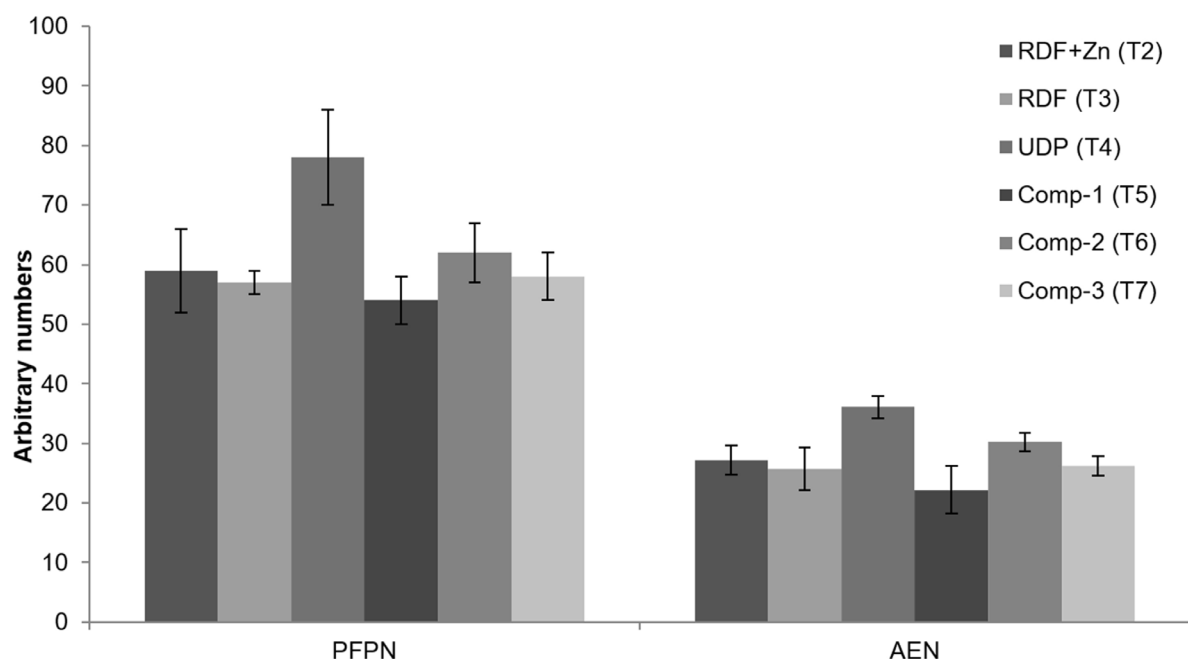
PFPN and AEN of different treatments are illustrated in Fig. 2. The higher PFPN (78 kg) and AEN (36.1 kg) was recorded in UDP treatment (T4) followed by blended fertilizer treatment (10:26:26 NPK) with values of 62 and 30.2 kg per kg N, respectively. It is desirable to have fertilizers with higher efficiencies so that more grain yield can be produced per unit of its application which not only contributes to food security but also reduces environmental hazards from excess nutrients (Fixen et al., 2014). The higher values of PFPN and AEN in UDP applied treatment can be attributed to a reduction in loss of nitrogen in different forms that usually happen with urea broadcasting (Halvorson & Del Grosso, 2013; Jiang, Lu, Zu, Zhou, & Wang, 2018). In accordance to the present findings, previous studies reported a higher agronomic nitrogen use efficiency of maize (25.8-47.31 kg grain per kg applied N) from deep placed urea compared to the conventional broadcast application at 90-135 kg N/ha (Agyin-Birikorang et al., 2020; Jiang, Lu, Zu, Zhou, & Wang, 2018; Jiang et al., 2019). The research finding is in line with previous studies which reported higher efficiency and effectiveness of UDP in reducing nitrogen loss and yield increment compared to conventional broadcast

method (Halvorson & Del Grosso, 2013; Jiang, Lu, Zu, Zhou, & Wang, 2018; Jiang et al., 2019).

Economic Analysis

The detailed result of the partial economic analysis is presented in Table 3. Treatment with urea deep placement method followed by RDF+Zn was found most economical for the cultivation of Khumal Hybrid-2 variety of maize with B:C ratio 1.94, 1.91, and benefit of US\$30.4/ha and US\$17.54/ha, respectively over RDF. Despite higher grain yield, blended fertilizer treatment (T6) showed a comparatively lower B:C ratio and benefit over RDF. Fertilizer blends used in the study were imported just for research purposes, hence were costly. If the government promotes blended fertilizers in the country, their price would be cheaper and farmers may get those fertilizers at a comparable price with DAP. Urea briquette, which is being produced domestically, is slightly expensive than normal urea, has the potential to replace granular urea with increased economic benefits from reduced labor costs and nitrogen loss. Though very limited research has been done in Nepal related to the deep placement of briquette urea in maize, studies conducted across the globe shows the sufficient evidence that UDP is more economical over the traditional urea broadcasting method (Agyin-Birikorang et al., 2020; Detchinli & Sogbedji, 2015).

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Remarks: RDF: recommended dose of fertilizer; UDP: urea deep placement; Comp- 1, Comp- 2, Comp- 3: three different type of compound (blended) fertilizers; PFPN: partial factor productivity of nitrogen; AEN: agronomic use efficiency of nitrogen

Fig. 2. Agronomic use efficiency and Partial Factor Productivity of Nitrogen in different treatments employed in the study

Table 3. Benefit-cost analysis of different treatments compared to government recommended doses estimated for a hectare of land

Treatments	Adjusted Yield (kg/ha)		Total Returns (US\$/ha)	Total variable cost (US\$/ha)	Cost Over RDF (US\$/ha)	Benefit over RDF (US\$/ha)	B:C ratio
	Grain	Stover					
CK	3431.46	10820	1019.4	733.5	-227.28	-596.27	1.39
RDF+Zn	6372.06	17050	1885.43	985.72	24.94	17.54	1.91
RDF	6206.68	19210	1842.95	960.78	0	0	1.92
UDP	6356.42	16640	1879.89	967.32	6.54	30.4	1.94
Comp- 1	5833.27	15260	1725.14	1047	86.22	-204.03	1.65
Comp- 2	6693.38	15450	1974.41	1112.36	151.58	-20.12	1.77
Comp- 3	6258.95	15270	1848.3	1135.87	175.09	-169.74	1.63

Remarks: CK: no fertilizer and manure application; RDF: recommended dose of fertilizer; UDP: urea deep placement; Comp- 1, Comp- 2, Comp- 3: three different type of compound (blended) fertilizers, (1 US\$= 121 Nepali Rupees)

CONCLUSION

This study concluded that urea deep placement with zinc sulfate (ZnSO_4) at 20 kg/ha reduced nitrogen input by 25% (90 kg/ha), produced similar grain yield (2.4% higher), higher agronomic nitrogen use efficiency (10.41 kg higher), and had more economic returns (US\$30.4) over the government recommended dose of fertilizers (120 kg/ha N). Treatment 120:60:60 NPK kg/ha + 20 kg/ha ZnSO_4 consisting of blended fertilizer (10:26:26 NPK), despite being economically less attractive, was found promising for increasing overall yield and yield attributing traits. If subsidized and promoted by the government, blended fertilizer can reduce the total amount of fertilizer import as single fertilizer supplies the NPK needs of the crops, and the application would be much convenient. On the other hand, the application of ZnSO_4 was found effective for increasing grain yield. However, this study could not quantify the optimum rate of ZnSO_4 to be used in combination with NPK fertilizers thereby flourishes novel scope of the study for future researches based on these preliminary findings.

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REFERENCES

- Adhikari, S. P., Timsina, K. P., Brown, P. R., Ghimire, Y. N., & Lamichhane, J. (2018). Technical efficiency of hybrid maize production in eastern terai of Nepal: A stochastic frontier approach. *Journal of Agriculture and Natural Resources*, 1(2), 189–196. <https://doi.org/10.3126/janr.v1i1.22234>
- Agyin-Birikorang, S., Tindjina, I., Adu-Gyamfi, R., Dauda, H. W., Fuseini, A. R. A., & Singh, U. (2020). Agronomic effectiveness of urea deep placement technology for upland maize production. *Nutrient Cycling in Agroecosystems*, 116, 179–193. <https://doi.org/10.1007/s10705-019-10039-8>
- Amare, D., Endalew, W., Yayu, N., Endeblihatu, A., Biweta, W., Tefera, A., & Tekeste, S. (2017). Evaluation and demonstration of maize shellers for small-scale farmers. *MOJ Applied Bionics and Biomechanics*, 1(3), 93–98. <https://doi.org/10.15406/mojabb.2017.01.00014>
- Badu-Apraku, B., Fakorede, M. A. B., Menkir, A., & Sanogo, D. (2012). *Conduct and management of maize field trials*. Ibadan, Nigeria: IITA. Retrieved from <http://biblio1.iita.org/bitstream/handle/20.500.12478/2124/U12BKlitaConductNothomDev.pdf?sequence=1&isAllowed=y>
- Bindraban, P. S., Dimkpa, C. O., White, J. C., Franklin, F. A., Melse-Boonstra, A., Koele, N., ... Schmidt, S. (2020). Safeguarding human and planetary health demands a fertilizer sector transformation. *Plants, People, Planet*, 2(4), 302–309. <https://doi.org/10.1002/ppp3.10098>
- Chimdess, D. (2016). Blended fertilizers effects on maize yield and yield components of Western Oromia, Ethiopia. *Agriculture, Forestry and Fisheries*, 5(5), 151–162. <https://doi.org/10.11648/j.aff.20160505.13>
- Choudhary, D., Khan, A. I., Poudyal, A., Thapa, A., Joshi, D., Kafle, D., ... Sharma, S. R. (2016). *Nepal seed and fertilizer project (NSAF)*. Lalitpur, Nepal. Retrieved from <https://www.cimmyt.org/projects/nepal-seed-and-fertilizer-project-nsaf/>
- Conijn, J. G., Bindraban, P. S., Schröder, J. J., & Jongschaap, R. E. E. (2018). Can our global food system meet food demand within planetary boundaries? *Agriculture, Ecosystems and Environment*, 251, 244–256. <https://doi.org/10.1016/j.agee.2017.06.001>
- Dawadi, D., & Sah, S. (2012). Growth and yield of hybrid maize (*Zea mays* L.) in relation to planting density and nitrogen levels during winter season in Nepal. *Tropical Agricultural Research*, 23(3), 218–227. <https://doi.org/10.4038/tar.v23i3.4659>
- Detchinli, K. S., & Sogbedji, J. M. (2015). Maize nitrogen use efficiency and yield as affected by fertilizer nitrogen form and rate of application in the guinea savanna agro ecological zone of West Africa. *International Journal of Current Research and Academic Review*, 3(10), 222–233. Retrieved from <http://www.ijcrar.com/vol-3-10/KodjoviSotomèDetchinliandJeanMianikpoSogbedji.pdf>
- FAOSTAT. (2020). Area, production and productivity of maize in South Asian countries. Retrieved from <http://www.fao.org/faostat/en/#data/QC>
- Fixen, P., Brentrup, F., Bruulsema, T., Garcia, F., Norton, R., & Zingore, S. (2014). Nutrient/fertilizer use efficiency: measurement, current situation and trends. In P. Drechsel, P. Heffer, H. Magen, R. Mikkelsen, & D. Wichelns (Eds.), *Managing Water and Fertilizer for Sustainable*

Krishna Dhakal et al.: *Briquette Urea Increases Maize Yield and Nitrogen Use Efficiency*.....

- Agricultural Intensificati* (pp. 1–30). Paris; Colombo; Norcross; Horgen: International Fertilizer Industry Association; International Water Management Institute; International Plant Nutrition Institute; International Potash Institute. Retrieved from https://www.fertilizer.org/images/Library_Downloads/2014_fue_chapter_1.pdf
- Fugice, J., Dimkpa, C., & Johnson, L. (2018). Slow and steady: The effects of different coatings on nitrogen release in soil. *Fertilizer FOCUS*, (September/October), 12–13. Retrieved from <https://ifdc.org/wp-content/uploads/2018/10/Fertilizer-Focus-Slow-and-Steady-Sept-Oct-2018.pdf>
- Halvorson, A. D., & Del Grosso, S. J. (2013). Nitrogen placement and source effects on nitrous oxide emissions and yields of irrigated corn. *Journal of Environmental Quality*, 42(2), 312–322. <https://doi.org/10.2134/jeq2012.0315>
- Jiang, C., Lu, D., Zu, C., Zhou, J., & Wang, H. (2018). Root-zone fertilization improves crop yields and minimizes nitrogen loss in summer maize in China. *Scientific Reports*, 8, 15139. <https://doi.org/10.1038/s41598-018-33591-9>
- Jiang, C., Ren, X., Wang, H., Lu, D., Zu, C., & Wang, S. (2019). Optimal nitrogen application rates of one-time root zone fertilization and the effect of reducing nitrogen application on summer maize. *Sustainability*, 11(10), 2979. <https://doi.org/10.3390/su11102979>
- Johnson II, F. E., Nelson, K. A., & Motavalli, P. P. (2017). Urea fertilizer placement impacts on corn growth and nitrogen utilization in a poorly-drained claypan soil. *Journal of Agricultural Science*, 9(1), 28–40. <https://doi.org/10.5539/jas.v9n1p28>
- KC, G., Karki, T. B., Shrestha, J., & Achhami, B. B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, 1(1), 1–9. <https://doi.org/10.3126/jmrd.v1i1.14239>
- Kugbe, J. X., Kombat, R., & Atakora, W. (2019). Secondary and micronutrient inclusion in fertilizer formulation impact on maize growth and yield across northern Ghana. *Cogent Food & Agriculture*, 5(1), 1700030. <https://doi.org/10.1080/23311932.2019.1700030>
- Liu, G., Zotarelli, L., Li, Y., Dinkins, D., Wang, Q., & Ozoires-Hampton, M. (2014). Controlled-release and slow-release fertilizers as nutrient management tools. *Institute of Food and Agricultural Sciences (IFAS)*, 2014(HS1255), 1–6. Retrieved from <https://edis.ifas.ufl.edu/pdf/HS/HS125500.pdf>
- Liu, W., Xiong, Y., Xu, X., Xu, F., Hussain, S., Xiong, H., & Yuan, J. (2019). Deep placement of controlled-release urea effectively enhanced nitrogen use efficiency and fresh ear yield of sweet corn in fluvo-aquic soil. *Scientific Reports*, 9, 20307. <https://doi.org/10.1038/s41598-019-56912-y>
- Lungu, O. I., & Dynoodt, R. F. (2008). Acidification from long-term use of urea and its effect on selected soil properties. *African Journal of Food, Agriculture, Nutrition and Development*, 8(1), 63–76. <https://doi.org/10.4314/ajfand.v8i1.19180>
- MoALD. (2018). *Statistical information on Nepalese agriculture 2073/74 (2016/17)*. Kathmandu, Nepal. Retrieved from <https://nepalindata.com/resource/statistical-information-nepalese-agriculture-207374-201617/>
- MoALD. (2020). *Agriculture and livestock diary* (Nepali). Lalitpur, Nepal. Retrieved from <https://aitc.gov.np/english/downloadsdetail/2/2019/19794382/>
- Njoroge, R., Otinga, A. N., Okalebo, J. R., Pepela, M., & Merckx, R. (2018). Maize (*Zea mays* L.) response to secondary and micronutrients for profitable n, p and k fertilizer use in poorly responsive soils. *Agronomy*, 8(4), 49. <https://doi.org/10.3390/agronomy8040049>
- Osti, N. P. (2019). Animal feed resources and their management in Nepal. *Journal of Food Processing & Technology*, 10, 34–35. <https://doi.org/10.4172/2157-7110-c1-110>
- Paudyal, K. R., Ransom, J. K., Rajbhandari, N. P., Adhikari, K., Gerpacio, R. V., & Pingali, P. L. (2001). *Maize in Nepal: production systems, constraints and priorities for research*. Kathmandu, Nepal. Retrieved from <https://repository.cimmyt.org/handle/10883/916>
- Ruffo, M., Olson, R., & Daverede, I. (2016). Maize yield response to zinc sources and effectiveness of diagnostic indicators. *Communications in Soil Science and Plant Analysis*, 47(2), 137–141. <https://doi.org/10.1080/00103624.2015.1108433>
- Sahrawat, K. L., Rego, T. J., Wani, S. P., & Pardhasaradhi, G. (2008). Sulfur, boron, and zinc fertilization effects on grain and straw quality of maize and sorghum grown in semi-arid tropical region of India. *Journal of Plant Nutrition*, 31(9), 1578–1584. <https://doi.org/10.1080/01904160802244712>

Krishna Dhakal et al.: *Briquette Urea Increases Maize Yield and Nitrogen Use Efficiency*.....

- Sangakkara, R., Amarasekera, P., & Stamp, P. (2011). Growth, yields, and nitrogen-use efficiency of maize (*Zea mays* L.) and mungbean (*Vigna radiata* L. Wilczek) as affected by potassium fertilizer in tropical South Asia. *Communications in Soil Science and Plant Analysis*, 42(7), 832–843. <https://doi.org/10.1080/00103624.2011.552663>
- Sapkota, A., Shrestha, R. K., & Chalise, D. (2017). Response of maize to the soil application of nitrogen and phosphorous fertilizers. *International Journal of Applied Sciences and Biotechnology*, 5(4), 537-541. <https://doi.org/10.3126/ijasbt.v5i4.18777>
- Sitienei, K., Kamiri, H. W., Nduru, G. M., & Kamau, D. M. (2018a). Effects of blended fertilizers on soil chemical properties of mature tea fields in Kenya. *Advances in Agricultural Science*, 06(04), 85–98. Retrieved from <http://aaasjournal.org/effects-of-blended-fertilizers-on-soil-chemical-properties-of-mature-tea-fields-in-kenya/>
- Sitienei, K., Kamiri, H. W., Nduru, G. M., & Kamau, D. M. (2018b). Nutrient budget and economic assessment of blended fertilizer use in Kenya tea industry. *Applied and Environmental Soil Science*, 2018, 2563293. <https://doi.org/10.1155/2018/2563293>
- SQCC. (2019). *Notified and denotified varieties of different crops till September 13, 2019*. Lalitpur, Nepal: Seed Quality Control Centre, Ministry of Agriculture and Livestock Development, Government of Nepal. Retrieved from http://sqcc.gov.np/images/category/Notified_and_Denotified_Varieties_till_2076_04_07.pdf
- TEPC. (2019). *Export import data bank*. Lalitpur, Nepal: Trade and Export Promotion Center, Ministry of Industry, Commerce and Supplies, Government of Nepal. Retrieved from <https://www.tepc.gov.np/>
- TFI. (n.d.). *The nutrient stewardship: 4R pocket guide*. Washington, DC. Retrieved from <https://nutrientstewardship.org/4r-pocket-guide/>