Biological Forum – An International Journal 13(1): 429-434(2021)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Productivity and Use Efficiencies of Maize (*Zea mays* L.) in Response to Split Application of Nitrogen

Md. Aziz[1], P.S. Patra[2], R. Saha[1] and A. S. Ahmed[1]*
[1]Research Scholar, Department of Agronomy,
Uttar Banga Krishi Viswavidyalaya, P.S- Pundibari, District-Cooch Behar, West Bengal-736165, India.
[2]Assistant Professor, Agronomy, Regional Research Station, Terai Zone,
Uttar Banga Krishi Viswavidyalaya, P.S-Pundibari, District-Cooch Behar, West Bengal-736165, India.

(Corresponding author: P.S. Patra)*
(Received 10 February 2021, Accepted 01 May 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Present investigation was carried out at the research farm of Uttar Banga Krishi Viswavidyalaya located at Cooch Behar district of West Bengal during crop season of 2016-17 to find out the optimum timing and amount of nitrogenous fertilizer to lessen the losses of applied nitrogen through leaching in light texture soil, thereby improving efficiencies and productivity of summer maize.
Experiment was laid out in randomized block design with six treatments and four replications. Treatments comprises of T_1 : Control (no fertilizer), T_2 : 90 kg N ha^{-1} at sowing + 30 kg N ha^{-1} at 35 DAS, T_3 : 60kg N ha^{-1} at sowing + 60 kg N ha^{-1} at 35 DAS, T_4 : 60 kg N ha^{-1} at sowing + 30 kg N ha^{-1} at 35 DAS + 30 kg N ha^{-1} at 55 DAS, T_5 = 40 kg N ha^{-1} at sowing + 40 kg N ha^{-1} at 35 DAS + 40 kg N ha^{-1} at 55 DAS and T_6 : 120 kg N ha^{-1} at sowing. Outcome of the experiment revealed that whenever nitrogen was applied in three equal splits (T_5) producing 202 % and 24.19 % more grain yield over T_1 and T_6. The highest net monetary return to the tune of Rs. 57157 ha^{-1} was recorded in T_5 while control plot gives negative return.

Key words: Economics, Maize, Nitrogen and Use efficiencies

INTRODUCTION

Maize (*Zea mays* L.) is one of the most vital cereal crops of the world and adds in mitigating food security in most of the developing countries. In India, maize is third most important food grains next to rice and wheat. Its significance lies in the fact that it is not only used for human food and animal feed but at the same time it is also extensively used for corn starch industry, corn oil production, baby corns, ethanol industry etc. which makes it one of the fastest growing cash crops in the world. It is cultivated over an area of 9.09 million hectares, with an annual production of 24.26 million metric tonnes and average national productivity of 2.56 metric tonnes per ha (Yadav *et al.*, 2015). Its production is growing at double the annual rate of that of rice and thrice that of wheat (Fischer *et al.*, 2014). Nitrogen is a major yield-determining factor required for maize production. Its availability in sufficient quantity throughout the growing season is essential for optimum maize growth. Nitrogen helps in cell enlargement, leaf area expansion and formation of chlorophyll thereby inducing photosynthetic ability (Lawrence *et al*., 2008; Uribelarrea *et al*., 2009; Diacono *et al.*, 2013; Namvar and Khandan, 2015). So lack of sufficient soil nitrogen leads to reduced leaf area, lessening the rate of photosynthesis and delayed growth and development which resulted into lower yield. On the other hand, disproportionate use of nitrogen to the soil results in escalation of production costs and adds to environmental pollution by contaminating ground water and contribute to the global warming due to release of nitrous oxide through nitrogen volatilization. Despite of application of recommended doses of nitrogen fertilizer in light texture soil, productivity and efficiency of applied fertilizer is not upto the expectation due to loses of nitrogenous fertilizer through leaching. With the intention to overcome the losses, splitting of nitrogenous fertilizer would be a viable option for in light textured soil. There were so many research findings of nitrogen rate, sources and methods of application but number and amount of spliitingon sandy loam soil is lacking. Therefore, to obtain good yield and improve the use efficiency of applied nitrogenous fertilizer, real time application of nitrogen is utmost necessary. Keeping the above facts in mind present experiment had been conceptualized to find out optimum splitting of nitrogen for better yields and use efficiencies.

MATERIALS AND METHODS

The study was carried out at research farm of Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal during crop season 2016-17. The soil of the research farm was sandy loam having pH 5.85. The initial organic carbon, available nitrogen, phosphorus and potassium were 0.52 %, 165.33, 22.82 and 174.68 kg ha^{-1} respectively. The amount of rainfall received during the crop growing season was 245.40 mm. During the period of experimentation (November to April) average maximum and minimum temperature was 31.13 & 9.66°C. The field experiment was laid in randomized block design with four replication and comprises of six treatmentsnamely T_1 : Control (no fertilizer) T_2 : 90 kg N ha^{-1} at sowing + 30 kg N ha^{-1} at 35 DAS, T_3 : 60kg N ha^{-1} at sowing + 60 kg N ha^{-1} at 35 DAS,T_4 : 60 kg N ha^{-1} at sowing + 30 kg N ha^{-1} at 35 DAS + 30 kg N ha^{-1} at 55 DAS, T_5 = 40 kg N ha^{-1} at sowing + 40 kg N ha^{-1} at 35 DAS + 40 kg N ha^{-1} at 55 DAS and T_6 : 120 kg N ha^{-1} at sowing. The experimental plot size was 5.2 m × 4 m. Maize (variety: DKC-9081) was sownon 16th November, 2016 with aspacing of 60 × 30 cm and harvested on 5th April, 2017. Except control plot, maize was fertilized with an N: P: K rates of 120: 60:60 kg ha^{-1}. Standard management practices were followed in all treatments. Growth parameters like plant height and dry matter accumulation were recorded 30 days interval starting from 30 days after sowingto harvest. Yield attributes like number of cobs plant^{-1}, cob length (cm), cob diameter (mm), number of kernel rows cob^{-1}, number of kernel cob^{-1}, seed index (g) and grain yield (t ha^{-1}) were recorded at harvest. The Physiological nitrogen use efficiency (PNUE), apparent recovery of applied nitrogen (ARN) and partial factor productivity for applied nitrogen (PFPN) agronomic nitrogen use efficiency (ANUE) were calculated using the formula described by Shilpashree *et al.,* (2011). Nitrogen biomass production efficiency (NBPE) and nitrogen uptake efficiency (NUE)was calculated using the formula suggested by Alam *et al.,* (2007) and Ajayi *et al.,* (2007) respectively.

RESULTS AND DISCUSSION

A. Plant height(cm)

Plant height of maize was recorded 15 days interval starting from 30 days after sowing to 90 days after sowing and presented in Table 1. It was clear from the table that plant height was increased continuously upto 90 days after sowing regardless of treatments. In all the sampling dates, except 30 days after sowing T_5 (40 kg N ha^{-1} at sowing + 40 kg N ha^{-1} at 35 DAS and 40 kg N ha^{-1} at 55 DAS) recorded significantly tallest plant (93.20 cm, 134.40 cm, 179.40 cm & 259.10 cm at 45, 60, 75, 90 days after sowing respectively) over absolute control plot (T_1), 120 kg N at sowing (T_6) and 90 kg N ha^{-1} at sowing + 30 kg N ha^{-1} at 35 DAS (T_2). Treatments receiving nitrogen in double equal split (T_3) and thrice unequal split were statistically non-significant. Higher plant height with spilt nitrogen was due to synchronize supply and better utilization of applied nitrogen throughout the growth stages of maize which intern augmented cell division and cell elongation. Rizwan *et al.,* (2003), Muthukumar *et al.,* (2005), Hassan *et al.,* (2010), Singh *et al.,* (2013) and Joshi *et al.,* (2014) also explored similar trend of result by integrated nutrient management.

B. Dry matter accumulation (g plant^{-1})

Dry matter accumulation was recorded at different stages of maize and presented in Table 1. It was reasonably perceptible that with the progression of growth stages, maize produces more dry matter irrespective of treatments. Nitrogen applied in three equal splits at sowing, 35 days after sowing and 55 days after sowing (T_5) produced significantly highest (2.31, 20.90, 89.38 and 174.86 g plant^{-1} at 30, 60, 90 and at harvest, respectively) dry matter over unfertilized control (T_1), 120 kg N ha^{-1} at sowing (T_6) and 90 kg N ha^{-1} + 30 kg N ha^{-1} (T_2) respectively. Higher dry matter buildup was might be due to higher photosynthesis and simultaneously translocation of more photo-synthates from source to sink. Treatment having no fertilizer (T_1) recorded significantly lowest (1.18, 9.02, 18.06 and 66.27 g plant^{-1} at 30, 60, 90 and at harvest respectively) dry matter irrespective of growth stages, might be due to lower number of leaves which in terns reduced photosynthetic capacity of plant. These resultsare in agreement with of Sitthaphanit *et al.,* (2010), Gehl *et al.,* (2005), Tadesse *et al.,* (2013), Nemati and Sharifi (2012), Saleem *et al.,* (2009) and Hafiz *et al.,* (2011).

Table 1: Plant height (cm) and dry matter accumulation (g plant^{-1}) of maize as influenced by split application of nitrogen.

Treatments	Plant height (cm)					Dry matter accumulation (g plant^{-1})			
	30 DAS	45 DAS	60 DAS	75DAS	90 DAS	30 DAS	60 DAS	90 DAS	At harvesting
T_1	41.93	63.10	81.05	97.85	126.90	1.18	9.02	18.06	66.27
T_2	46.15	88.75	128.60	156.35	240.50	1.85	15.18	72.18	139.69
T_3	46.50	90.00	129.15	167.55	255.30	2.10	19.02	83.66	144.17
T_4	49.50	91.75	133.25	171.33	256.15	2.18	20.44	85.90	169.43
T_5	49.85	93.20	134.40	179.40	259.10	2.31	20.90	89.38	174.86
T_6	43.10	85.40	123.20	143.00	211.90	1.42	13.06	71.52	126.27
S Em.(±)	3.04	2.58	3.37	6.91	10.82	0.13	1.98	3.49	4.40
CD (p = 0.05)	NS	7.93	10.52	18.03	32.90	0.42	6.04	10.62	13.38

C. Yield attributes & grain yields

Yield attributes namely cob length, cob diameter; number of kernel rows cob^{-1}, number of grains row^{-1}, number of grains cob^{-1} and 1000 grain weightwere recorded at the time of harvesting and presented in Table 2. All the yield attributes were found to be highest in the treatment which received nitrogen in three equal splits (T_5) followed by T_4 and T_3, though all are statistically at par. It was observed that application of nitrogen in three splits with uneven proportions gives better result than at double and single dose. Treatment receiving no fertilizer (T_1) produced statistically lowest values of yield attributes might be due to non-availability of nutrients, particularly nitrogen at vital growth stages of maize. Higher values of yield attributes ultimately helped in producing higher grain (10.41 t ha^{-1}) and stover yield (16.97 t ha^{-1}) corresponding to T_5 (40 kg N ha^{-1} at sowing + 40 kg N ha^{-1} at 35 DAS + 40 kg N ha^{-1} at 55 DAS) and it was followed by T_4 (60 kg N ha^{-1} at sowing + 30 kg N ha^{-1} at 35 DAS + 30 kg N ha^{-1} at 55 DAS) and T_3 (60 kg N ha^{-1} at sowing + 60 kg N ha^{-1} at 35 DAS). Higher grain yield is simply due to better synchronization of applied nitrogen with the crop demand which interns facilitated better root growth thus higher extraction of nutrients from soil environment which leads to better translocation of photo-synthates from source to sink.Similar findings were also scrutinized by Tadesse *et al.,* (2013), Nemati and Sharifi (2012), Saleem *et al.,* (2009), Hafiz *et al.,* (2011), Zeidan *et al.,* (2006), Lawrence *et al.,* (2008), Mariga *et al.,* (2000), Scharf *et al.,* (2002) and Subedi and Ma (2005).

D. Nitrogen harvest index (NHI)

It is an important index which denotes re-translocation of captivated nitrogen from vegetative plant parts to the grain. Nitrogen harvest index was calculated and presented in Table 2. Highest nitrogen harvest index of 0.84 was obtained whenever nitrogen was applied in three equal splits *ie*. 40 kg N at sowing + 40 kg N at 35 DAS + 40 kg N at 55 DAS may be due to the translocation of absorbed nitrogen more capably from the vegetative part to the economic part. Lawrence *et al.,* (2008) and Zeidan *et al.,* (2006) reported higher harvest index with enhance rate of nitrogen fertilization in maize. Treatment receiving no fertilizer attained lowest nitrogen harvest index of 0.67.

Table 2: Yield attributes and yields of maize as influenced by split application of nitrogen.

Treatments	Cob length (cm)	Cob diameter (cm)	No of rows cob^{-1}	No of grain row^{-1}	No of grain cob^{-1}	1000 grain weight (g)	Grain Yield (t /ha)	Stover yield (t /ha)	Nitrogen Harvest Index (NHI)
T_1	11.16	11.21	11.28	11.10	125.15	195.92	3.44	8.81	0.67
T_2	15.40	14.85	14.80	24.94	348.85	268.25	8.24	14.49	0.80
T_3	18.05	16.04	16.08	29.25	491.73	283.52	9.63	15.84	0.81
T_4	18.08	16.08	16.35	30.70	509.58	300.18	9.74	16.41	0.82
T_5	18.13	17.47	16.59	31.87	528.51	307.60	10.41	16.97	0.84
T_6	14.94	13.77	14.33	26.07	306.15	252.81	8.06	13.69	0.78
S Em.(±)	1.21	0.16	0.38	0.89	53.12	4.60	0.76	0.73	-
CD (p = 0.05)	2.35	0.50	1.17	2.71	167.25	13.99	2.12	2.18	-

E. Nitrogen content (%) and uptake (Kg ha^{-1})

It was manifested from the data presented in Table 3, that N content in grain and stover were varied due to different timing and amount of nitrogen application. Nitrogen applied in three equal split (40 kg N ha^{-1} at sowing + 40 kg N ha^{-1} at 35 DAS + 40 kg N ha^{-1} at 55 DAS) recorded significantly highest grain (1.85%) and stover (0.32%) nitrogen over the treatment receiving full amount of nitrogen at sowing (T_6) and control plot (T_1). Nitrogen uptake was significantly higher by 384.26 and 91.06 per cent in T_5 over control plot (T_1) and single application of nitrogen (T_6 = 120 kg N ha^{-1} at sowing). The probable reason might be due to effectual absorption, translocation and utilization of applied nitrogen. Nitrogen applied in differential splits and volume fails to attain levels of significance. It was observed that nitrogen uptake by stover as compared to grain is higher in control plot was due poor translocation of absorbed nitrogen towards grains.

Total nitrogen uptake (180.62 kg ha^{-1}) was found to be significantly higher under T_5 (40 kg N ha^{-1} at sowing + 40 kg N ha^{-1} at 35 DAS + 40 kg N ha^{-1} at 55 DAS) which was 287.76 % and 87.42 % more than control (T_1) and single application of nitrogen at sowing (T_6). This may be attributed to better crop growth and higher uptake of nutrients in the above treatment and may be enhanced nitrogen use efficiency with more appropriate nitrogen rates and better timing of nitrogen application. Our results are in covenant with remarks ended by Subedi and Ma, 2005.

Use efficiencies of nitrogen: Response of split application of nitrogen on use efficiencies was reasonably apparent in this experiment and presented in Table 4.

Physiological nitrogen use efficiency (PNUE): Physiological nitrogen use efficiency (PNUE) was found highest (83.64 %) under the treatment receiving 120 kg N ha^{-1} at the time of sowing (T_6) might be due to higher grain yield as compared to nitrogen uptake over other treatments.

Table 3: Effect of split application of nitrogen on nitrogen content and uptake by maize.

Treatments	N content in grain (%)	N Content in Stover (%)	Nitrogen uptake by grain (kg ha^{-1})	Nitrogen uptake by stover (kg ha^{-1})	Total uptake (kg ha^{-1})
T_1	0.78	0.09	31.25	15.33	46.58
T_2	1.53	0.19	87.12	21.71	108.83
T_3	1.61	0.25	101.44	23.62	125.06
T_4	1.72	0.29	125.23	27.51	152.74
T_5	1.85	0.32	151.33	29.29	180.62
T_6	1.42	0.14	75.62	20.75	96.37
S Em. (±)	0.08	0.03	14.87	2.66	15.02
CD (P = 0.05)	0.29	0.12	32.12	7.29	43.77

Table 4: Use efficiencies of nitrogen as influenced by split application of nitrogen in Maize.

Treatments	Physiological nitrogen use efficiency	Apparent nitrogen recovery (%)	Partial factor productivity (PFP_N)	Nitrogen uptake efficiency (%)	Agronomic efficiency (%)	Nitrogen biomass production efficiency (NBPE)
T_1	73.85	00	00	00	00	43.23
T_2	77.09	51.88	69.92	90.69	41.25	64.34
T_3	77.00	65.40	80.25	104.22	51.58	61.04
T_4	63.77	88.47	81.17	127.28	52.50	63.04
T_5	57.63	111.70	86.75	150.52	58.08	59.70
T_6	83.64	41.49	67.17	80.31	38.50	60.85

Nitrogen applied in three equal split recorded lowest value (57.63%) of PNUE. Similar findings were also reported by Muthukumar *et al.*, (2007), Gehl *et al.*, (2005), Rizwan *et al.*, (2003) and Foulkes *et al.*, (2009).

Apparent recovery of applied nitrogen (ARN): Apparent recovery of applied nitrogen(ARN) was varied from 41.49 to 111.70 % among the nitrogen treated plot. Whenever nitrogen was applied in three equals split *i.e.* 40 kg N ha^{-1} at sowing + 40 kg N ha^{-1} at 35 DAS + 40 kg N ha^{-1} at 55 DAS (T_5) recovered highest (111.70%) nitrogen which was followed by treatment receiving 60 kg N ha^{-1} at sowing + 30 kg N ha^{-1} at 35 DAS + 30 kg N ha^{-1} at 55 DAS (T_4). This is due to synchronize availability of nutrients throughout the growth stages of maize, thereby improving uptake and finally grain yield. The results are in close conformity with those of Muthukumar *et al.*, (2007), Gehl *et al.*, (2005), Rizwan *et al.*, (2003) and Foulkes *et al.*, (2009).

Partial factor productivity (PFP_N): Partial factor productivitywas found highest (86.75 %) under T_5 and lowest (67.17 %) is being under (T_6) might be due to pronounced effect of split application on nitrogen towards grain yield. The results are in close conformity with those of Muthukumar *et al.*, (2007), Gehl *et al.*, (2005), Rizwan *et al.*, (2003) and Foulkes *et al.*, (2009).

Nitrogen uptake efficiency (%): Higher uptake efficiency (150.52 %) was found under T_5 (40 kg N ha^{-1} at sowing + 40 kg N ha^{-1} at 35 DAS + 40 kg N ha^{-1} at 55 DAS) followed by T_4 (127.28%), T_3 (104.22%) and T_2 (90.69%). Lowest value of uptake efficiency (80.31 %) was found under T_6 (120 kg N ha^{-1} at sowing). Nitrogen uptake efficiency more than 100 % indicated that removal of nitrogen is more as compared to addition, and the excess amount of nitrogen had been taken by maize from the organic pool or the residual nitrogen from fertilizer applied to preceding crop. A similar finding was also reported by Francis & Schepers, (1994).

Agronomic efficiency (AE): Agronomic efficiency was varied from 38.50 to 58.08 % among the treatments receiving nitrogen in different timing and amount. Whenever nitrogen was applied in three equal split (T_5) achieved highest efficiency over single application of nitrogen at sowing (T_6). Results are in close conformity with Muthukumar *et al.*, (2007), Gehl *et al.*, (2005), Rizwan *et al.*, (2003), Foulkes *et al.*, (2009), Zhao *et al.*, (2006), Halvorson *et al.*, (2001), Lopez and Bellido, 2001.

Nitrogen biomass production efficiency (NBPE): Nitrogen biomass production efficiency was found highest (64.34) in T_2 where nitrogen was applied in two split 90 kg N at sowing + 30 kg N at 35 DAS and while unfertilized control plot (T_6) recorded lowest (43.23 %) NBPE. Similar findings were also scrutinized by Muthukumar *et al.*, (2007), Gehl *et al.*, (2005), Rizwan *et al.*, (2003) and Foulkes *et al.*, (2009).

F. Economics of maize production

From the Table 5 it was revealed that treatment receiving nitrogen in three equal split (40 kg N at sowing + 40 kg N at 35 DAS + 40 kg N at 55 DAS) fetched higher gross return to the tune of Rs. 104100 and net return to the tune of Rs. 57157, which was followed by T_4 (Rs. 97400 & Rs. 50457) and T_3 (Rs. 96300 and Rs. 49357). Unfertilized control plot (T_1) recorded lowest gross return to the tune of Rs. 34400.00 simply due to lower grain yield. Negative net return and return/rupee investment was noticed in control plot, due to higher cost of cultivation as compared to gross return. Highest return/rupee investment (1.22) was realized when nitrogen applied in three equal splits followed by T_4 (1.07) and T_3 (1.05). Similar findings have also been reported by Sharifi and Namvar (2016), Bindhani *et al.*, (2007), Sitthaphanit *et al.*, (2010), Tadesse *et al.*, (2013) and Dubey *et al.*, (2006).

Table 5: Economics of maize cultivation as influenced by split application of nitrogen.

Treatments	Grain yield (t ha^{-1})	General cost of cultivation (Rs. ha^{-1})	Cost of treatment (Rs. ha^{-1})	Total Cost (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Return/ rupee investment
T_1	3.44	40231.00	0.00	40231.0	34400.00	-5831	-0.14
T_2	8.39	40230.00	6712.00	46943.0	83900.00	36957	0.79
T_3	9.63	40230.00	6712.00	46943.0	96300.00	49357	1.05
T_4	9.74	40230.00	6712.00	46943.0	97400.00	50457	1.07
T_5	10.41	40230.00	6712.00	46943.0	104100.00	57157	1.22
T_6	8.06	40230.00	6712.00	46943.0	80600.00	33657	0.72

CONCLUSION

The findings indicates that application of 120 kg nitrogen in three equal splits along with 60 kg phosphorus and potassium ha^{-1} was found superior for improving the productivity and profitability of maize through maximizing efficiencies of applied nitrogen, thus it is recommended for the farmers of terai region having sandy loam soil.

FUTURE SCOPE

As maize is a nitro-positive crop so, there is a possibility to increase the amount of nitrogen beyond 120 kg ha^{-1} in order to maximizing yield. Therefore, an investigation may be carried out for optimization of nitrogen dose and real time application for light textured soil.

Conflict of interest: No conflict of interest exist.

ACKNOWLEDGEMENT

The authors are thankful to Directorate of Farms and Directorate of Research of Uttar Banga Krishi Viswavidyalaya for financial support.

REFERENCES

Ajayi, O.C., Akinnifesi, F. K., Mitti, J., de Wolf, J., Matakala, P., & Kwesiga, F. (2007). Adoption, economics and impact of agroforestry technologies in southern Africa. In D. R. Batish, R. K. Kohli, S. Jose, & H. P. Singh (Eds.), Ecological Basis of Agroforestry. Taylor & Francis/CRC Press.ch18.

Alam, M.S., Nesa, M.N., Khan, S.K., Hossain, M.B. and Hoque, A. (2007). Varietal differences on yield and yield contributing characters of wheat under different levels of nitrogen and planting methods. *Journal of Applied Science Research*, **3**(11): 1388-1392.

Bakht, J., Ahmad, S., Tariq, M., Akber, H. and Shafi, M. (2006). Response of maize to planting methods and fertilizer N. *Journal of Agriculture and Biological Science*, **1**: 8–14.

Bindhani, A., Barik, K.C., Garnayak, L.M. and Mahapatra, P. K. (2007). Nitrogen management in baby corn (*Zea mays* L.). *Indian Journal of Agronomy*, **52**(2): 135-138.

Diacono, M., Rubino, P. and Montemurro, F. (2013). Precision nitrogen management of wheat: a review. *Agronomy for Sustainable Development*, **33**(1): 219–241.

Dubey, S., Purohit, K.K., and Sarawgi, S.K. (2006). Effect of integrated nitrogen management on yield and yield attributes of hybrid maize (*Zea mays* L.). *Journal of Agricultural Science*, **11**(2): 79-81.

Fischer, R.A., Byerlee, D. and Edmeades G.O. (2014). Crop yields and global food security: will yield increase continue to feed the world? ACIAR Monograph No. 158, Australian Centre for International Agricultural Research, Canberra, xxii + 634 pp.

Francis, D. D. and Schepers, J.S. (1994). Nitrogen uptake efficiency in maize production using irrigation water production using irrigation water high in nitrate. *Fertility Research*, **39**: 239-244.

Gehl, R.J., Schnidt, J.P., Maddux, L.D. and Gordon, W.B. (2005). Corn yield response to nitrogen rate and timing in sandy irrigated soil. *Agronomy Journal*, **97**: 1230-1238.

Hafiz, M. H., Ashfaq, A.,Wajid, A., and Javaid, A. (2011). Maize response to time and rate of nitrogen application. *Pakisthan Journal of Botany*, **43**(4): 1935-1942.

Halvorson, A.D., Wienhold, B.J., and Black, A.L. (2001). Tillage and nitrogen fertilization influence grain and soil nitrogen in an annual cropping system. *Agronomy Journal*, **93**: 836–841.

Hassan, U.L., Fateh, C.O., Shamasuddin, T., Gandahi, A., Siddiqui, M.H., Oad, S. M., and Jagirani, A.W. (2010). Effect of N application and N splitting strategy on maize N uptake, biomass production and physio-agronomic characteristics. *Sarhad Journal of Agriculture*, **26**(4): 551-558.

Lawrence, J.R., Ketterings, Q.M., and Cherney, J.H. (2008). Effect of nitrogen application on yield and quality of corn.*Agronomy Journal*, **100**(1): 73–90.

Lopez-Bellido, R.J., and Lopez-Bellido, L. (2001). Efficiency of nitrogen in wheat under Mediterranean condition: effect of tillage, crop rotation and N fertilization. *Field Crop Research*, **71** (1): 31–64.

Mariga, I.K., Jonga, M., and Chivinge, O.A. (2002). The effect of timing of application of basal and topdressing fertilizers on maize yield at two rates of basal fertilizer. *Crop Research*, **20**: 372–80.

Muthukumar, V.B., Velayudham, K., and Thavaprakaash, N. (2005). Growth and yield of baby corn (*Zea mays* L.) as influenced by plant growth regulators and different time of nitrogen application. *Research Journal of Agriculture and Biological Science*, **1**(4): 303-307.

Namvar, A., and Khandan, T. (2015). Inoculation of rapeseed under different rates of inorganic nitrogen and sulfur fertilizer: impact on water relations, cell membrane stability, chlorophyll content and yield. *Archives of Agronomy Soil Science*, **61**(8): 1137–1149.

Rahmati, H. (2009). Effect of plant density and nitrogen rates on yield and nitrogen use efficiency of grain corn. *World Applied Science Journal*, **7**(8): 958–61.

Rizwan, M., Maqsood, M., Rafiq, M., Saeed, M., and Ali, Z. (2003). Maize (*Zea mays* L.) response to split application of Nitrogen. *International Journal of Agriculture and Biology*, **5**(1): 19-21.

Saleem, M. F., Randhawa, M. S., Hussain, S. M., Wahid, A., and Anjum, S.A. (2009). Nitrogen management studies in autumn planted maize (*Zea mays* L.) hybrids. *Journal of Animal and Plant Science,* **19**(3): 140-143.

Scharf, P.C., Wiebold, W.J., and Lory, J.A. (2002). Yield response to nitrogen fertilizer timing and deficiency level. *Agronomy Journal*, **94**: 435–441.

Sharifi, R.S., and A. Namvar (2016). Effects of rates and nitrogen application timing on yield, agronomic characteristics and nitrogen use efficiency in corn. *International Journal of Agriculture and Crop Science*, **4**(9): 534-539.

Singh, M.V., Mishra, B.N., and Kumar, N. (2013). Effect of nitrogen scheduling on rabimaize. *Annals of plant and soil research*, **15**(2): 171-172.

Sitthaphanit, S., Limpinuntana, V., Toomsan, B., Panchen, S.W., and Bell, R. (2010). Growth and Yield Responses in Maize to Split and Delayed Fertilizer Applications on Sandy Soils under High Rainfall Regimes. *Kasetsart Journal of Natural Science,* **44**: 991-1003.

Subedi, K.D., and Ma, B.L. (2005). Nitrogen uptake and partitioning in stay green and leafy maize hybrids. *Crop Science*, **45**: 740–47.

Tadesse, T., Assefa, A., Liben, M., and Tadesse, Z. (2013). The effect of nitrogen fertilizer split application on the nitrogen use efficiency, grain yield & economic benefit of maize production. *International Journal of Agricultural Science,* **3**(5): 493-499.

Uribelarrea, M., Crafts-Brandner, S.J., and Below, F.E. (2009). Physiological N response of field-grown maize hybrids (*Zea mays* L.) with divergent yield potential and grain protein concentration. *Plant and Soil,* **31**(6): 151–60.

Verma, N.K., Pandey, B.K., Singh U.P., and Lodhi, M.D. (2012). Effect of sowing dates in relation to integrated nitrogen management on growth, yield and quality of Rabi maize. *Journal of Animal and Plant Science,* **22**(2): 324-329.

Yadav, O. P., Hossain, F., Karjagi, C. G., Kumar, B., Zaidi, P. H., Jat, S.L., Chawla, J.S., Kaul, J., Hooda, K.S., Kumar, P., Yadava, P., and Dhillon B.S. (2015). Genetic improvement of maize in India – retrospect and prospects. *Agricultural Research,* **4**: 325–38.

Zeidan, M.S., Amany, A., and Kramany, M. F.El. (2006). Effect of N-fertilizer and plant density on yield and quality of maize in sandy soil. *Research Journal of Agriculture and Biological Science,* **2**(4): 156–61.

How to cite this article: Md. Aziz, Patra, P.S., Saha, R. and Ahmed, A.S. (2021). Productivity and Use Efficiencies of Maize (*Zea mays* L.) in Response to Split Application of Nitrogen. *Biological Forum – An International Journal*, **13**(1): 429-434.