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Full Length Research Paper

The effect of nitrogen fertilizer split application on the nitrogen use efficiency, grain yield and economic benefit of maize production

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An experiment was conducted at Adet Research station, northwest-Ethiopia in order to determine the influence of the application time of nitrogen fertilizer on two varieties of maize (*Zea mays*). A split plot design in randomized complete block (RCB), with three replicates was used. Variety was the main plot and fertilizer application time the sub-plot. Intermediate maturing and late maturing maize varieties, BH-540 and BH-660, respectively, were used for the experiment. Ten different times of nitrogen fertilizer application were studied: 1/2 at planting (p) + 1/2 at knee height (k) (control), all at planting, 1/2 p + 1/2 near tasseling (t), 1/3 p + 1/3 k + 1/3 t, 1/3 p + 2/3 k, 1/3 p + 2/3 t, 1/4 p + 2/4 k + 1/4 t, 1/4 p + 1/4 k + 2/4 t, 1/4 p + 3/4 k, and 1/4 p +3/4 t. The same rate of nitrogen, 128 kg N /ha, was used in all the cases. Results obtained indicated that for the intermediate maturing BH-540 variety nitrogen application of 1/3 at planting + 2/3 at knee height was found to produce the highest yield. The application method gave a yield advantage of 1005 kg/ha over the commonly practiced 1/2 at planting + 1/2 at knee height application. Concerning the late maturing variety BH-660, nitrogen application of 1/4 at planting + 3/4 at knee height gave a yield advantage of 296.2 kg/ha over 1/2 at planting + 1/2 at knee height application. The best yielding split applications and timings exhibited the highest agronomic Nutrient Use Efficiencies (NUE) and better economic advantages for the respective varieties.

Key words: Nitrogen split, medium maturing, late maturing, profitable, nutrient use efficiency*, zea mays.*

INTRODUCTION

Maize *(Zea mays)* is the third most important cereal crop in the world next to rice and wheat, and has the highest production potential among the cereals (Muthukumar *et al*., 2007). It is the most important nutrient for people in Central and South America, Africa and China (Khalily *et al*. 2010; Wondesen and Sheleme 2011). Average productivity of maize is 6.7 t ha^{-1} in developed countries and 2.4 t ha^{-1} in developing countries (Khalily *et al*. 2010). In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands (Wondesen and Sheleme 2011). It is one of the most important cereal crops, that allow the food self-sufficency program of the country, playing a key role in the human diet and animal feed, providing adequate amounts of energy and protein (Wondesen and Sheleme 2011).

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Maize ranks first in productivity and third in area coverage of the major cereal crops produced in northwestern Ethiopia (Alelign and Regassa, 1992; UNDP, 1996; CSA, 2003). Its average yield has remained at 15 q/ha, which is lower than the national average, 17 q/ha, and is by far lower than the world average (UNDP, 1996). Various yield limiting factors contribute for the lower yield of maize, poor soil fertility being one of the principal factors which hamper maize production in Ethiopia (Alelign and Regassa, 1992; Abebayehu *et al*., 2011; Wondesen and Sheleme 2011). Nutrient inputs from chemical fertilizers are needed to replace nutrients which are removed and lost during cropping, to maintain positive nutrient balance (Buah and Mwinkaara 2009). Nitrogen, together with phosphorous, is one of the most limiting macronutrients to maize grain yield Worldwide (Hefny and Aly 2008). Nitrogen availability influences the uptake, not only of itself, but also of other nutrients (Onasanya et al., 2009), as N-fertilized plants usually have larger root systems, which enhances the capture of other nutrients (Masaka, 2006). Since nitrogen is highly mobile, its use and demand is continuously increasing (Abd El-Lattief 2011), as it is subjected to high loss from the soil plant system (Abd El-Lattief 2011). Even under the best management practices 30-50% of applied N is lost through different agencies and hence the farmer is compelled to apply more than the crop needs to meet the loss (Abd El-Lattief 2011). The loss of N not only costs the farmer but it also has hazardous impact on the environment. In high and medium altitude maize growing areas where rainfall is high, most of the nitrogen is lost through leaching and denitrification making the nutrient unavailable during the critical stages of crop growth. Many strategies have been developed to mitigate nutrient leaching and improve the nutrient use efficiency (NUE). Nitrification inhibitors,which slow the oxidation of NH_4, and enhances slow and controlled release fertilizers, have been used to reduce N leaching (Sitthaphanit *et al.*, 2010). Furthermore, soil management practices, such as incorporating straw with a high C:N ratio and minimum tillage can reduce N leaching. While the above strategies, based on alternative fertilizer types, can be effective in reducing leaching, the extra cost of such products often makes them prohibitive for use by small holders in rain-fed environments. Furthermore, the timing of any fertilizer application is another low-cost strategy to reduce nutrient leaching, so that nutrient supply is synchronized with plant nutrient demand (Gehl *et al.*, 2005). Split application of nitrogen has been reported to be one of the methods to improve nitrogen-nutrient use by the crop while reducing the nutrient loss through leaching and volatilization (Mungai *et al.* 1998; Tolessa *et al.* 1994). Split application is an essential approach to increase the N Use efficiency in crops (Muthukumar *et al*., 2007).Split fertilizer application has already proved to enhance maize grain yield. It showed to increase the economic benefit due to the increase in grain yield (Sitthaphanit *et al.*, 2010). Moreover, split applications reduced total N leaching and increase nutrient uptake (Sitthaphanit *et al.*, 2010). Mitigation of nutrient leaching by management practices, such as synchronizing plant nutrient uptake with demand can improve the Nutrient Use Efficiency (NUE) of the plant (Gehl *et al.*, 2005). Fine-tuning rate and time by split application in order to coincide nitrogen availability with crop needs is a best management practice that would result in better N use efficiency and yield. Most soils in Ethiopia are responsive to split application of nitrogen for maize production (Tolessa *et al.,* 1994). Presently, a blanket nitrogen split application recommendation of 1/2 of the total at planting and the remaining 1/2 at knee height is being widely used in northwestern Ethiopia. However, some farmers in the region have observed good responses of the crop by reducing the amount of nitrogen at planting and applying more at later growth stages (personal communication). Therefore, this study was conducted with the objective of determining the optimum nitrogen fertilizer split application time for the intermediate and late maturing maize varieties BH-540 and BH-660, respectively.

MATERIALS AND METHODS

The experiment was conducted for two consecutive cropping seasons at Adet Research station, northwest-Ethiopia. The altitude of the site is 2240 MASL receiving a mean total annual rainfall of 1156.9 mm of which about 70 % are received during the main cropping season in the months from June to September (Figure 1). It has average daily maximum and minimum temperatures of 26.1^0C and 9.7^0C, respectively (Figure 2). The experimental site has a nitosol soil with an average soil pH of 5.17, available P (Olsen) of 1.688 PPM, total nitrogen 0.0949% and soil organic matter of 1.898 % (Table 1). The experimental design used was split plot with three replications. Variety was the main plot and time of fertilizer application was the sub-plot. A medium maturing variety, BH-540, and a late maturing variety, BH-660, were used. Ten different times of nitrogen fertilizer application were studied. The application times were 1/2 at planting + 1/2 at knee height (control), all at planting, 1/2 at planting + 1/2 at near tasseling, 1/3 at planting + 1/3 at knee height + 1/3 at near tasseling, 1/3 at planting + 2/3 at knee height, 1/3 at planting + 2/3 at near tasseling, 1/4 at planting + 2/4 at knee height + 1/4 at near tasseling, 1/4 at planting + 1/4 at knee height + 2/4 at near tasseling, 1/4 at planting + 3/4 at knee height and 1/4 at planting + 3/4 at near tasseling. The same rate of nitrogen, 128 kg N /ha, as granules of Urea, was used in all cases. Nitrogen was applied at hills around each plant. Phosphorous fertilizer at a rate of 92 kg P_2O_5/ha was applied to all plots at planting. A gross and net plot sizes of 3.75 m X 4.8 m and 2.25 m x 4.8 m, respectively were used for each sub plots. Data was collected on labor (man days) needed for fertilizer application, grain yield, plant height, thousand seeds weight and grain price.

Statistical analysis was performed for grain yield, plant height and thousand seeds weight using Statistical Analysis System (SAS) Version 9.2 (SAS Inc., 2002). Means of the significant treatments were separated using the least significant difference (LSD) at 5% level. Economic analysis was also performed following the CIMMYT partial budget methodology (CIMMYT, 1988). A two years harvesting months (December-February) average price of Ethiopian Birr 3/kg maize grain and the prevailing labour cost in the area Ethiopian Birr 15 per man day was taken for the economic analysis. Agronomic Nitrogen Use Efficiency (NUE) was calculated as extra kilogram of grain per extra kilogram of N applied (Hatfield and Prueger, 2004).

RESULTS

Application time caused significant variation in response of maize grain yield (Tables 2). For the medium maturing

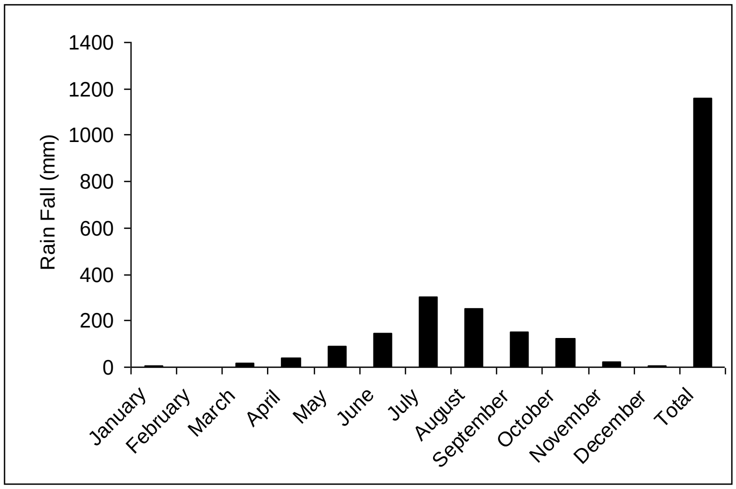

Figure 1. Average and total rain fall of Adet Research Station (1996-2009)

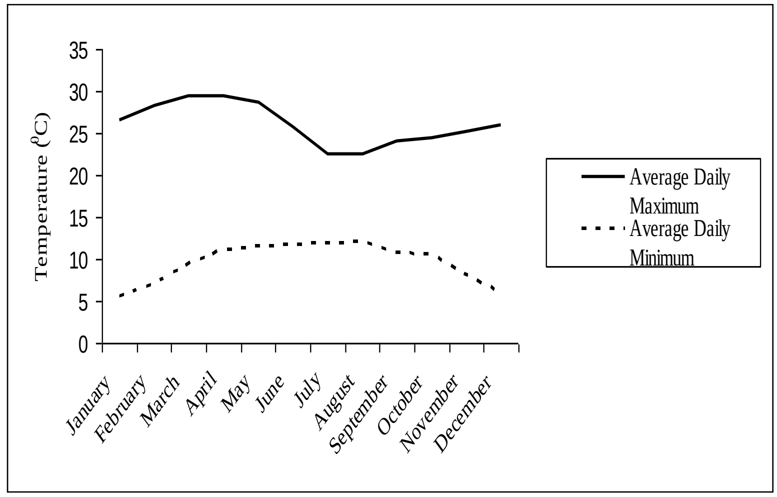

Figure 2. Average daily maximum and minimum temperatures at Adet

Table 1. Some soil chemical characteristics of sample taken before planting.

Available P (Olsen) (ppm)	1.688
Total N %	0.0949
Organic Matter %	1.898
pH	5.17

variety, BH-540, the highest grain yield (7908.0 kg/ha) was observed when nitrogen was applied 1/3 at planting and 2/3 at knee height (Table 2). The particular application exhibited a yield advantage of 1005.4 kg/ha over the control (1/2 at planting+1/2 at knee height). In the case of the late maturing variety, BH-660, the highest yield, 8182.0, was obtained when nitrogen was applied 1/4 at planting and 3/4 at knee height (Table 2). The application exhibited a yield advantage of 296.0 kg/ha over the 1/2 at planting+1/2 at knee height application (control).The grain yield analysis indicated that both BH-540 and BH-660 need more of their nitrogen to be applied at knee height than at planting. It also indicate that the late maturing variety, BH-660, need most of its nitrogen at latter growth stages. At the time of planting, the medium maturing BH-540 need relatively more nitrogen (1/3) than the late maturing BH-660 which need 1/4 of the total nitrogen. Here it can be concluded that for medium maturing varieties like BH-540 nitrogen should be applied 1/3 of it at planting and the remaining 2/3 at knee height. Concerning late maturing varieties like BH-660, 1/4 of the nitrogen should be applied at planting while the rest 3/4 at knee height. The statistical analysis for plant height indicated that plant height was significantly affected by timing and proportion of nitrogen fertilizer application (Table 3). The highest plant height in case of BH-540 variety was observed for nitrogen application of 1/3 at planting and 2/3 at knee height. In case of the variety BH-660, it was the 1/4 at planting and 3/4 at tillering application that exhibited the lowest plant height while the other treatments showed equivalent heights. Thousand seeds weight of the BH 660 variety but not of BH 540 was significantly affected by timing and proportion on nitrogen fertilizer application (Table 3). Though it was statistically non significant, the 1/3 at planting and 2/3 at knee height application resulted in the highest thousand seeds weight of BH-540 variety. The economic analysis indicated that in case of BH-540 the nitrogen application of 1/3 at planting and 2/3 at knee height was the best method since it gave the highest net benefit (Table 4). Regarding BH-660, when nitrogen was applied 1/4 at planting and 3/4 at knee height the highest net benefit realized (Table 5). According to the results of the economic analysis, only by adjusting the amount to the split application at different stages, higher economic benefits were realized. In the case of the medium maturing

Table 2. The effect of nitrogen fertilizer application time on the grain yield of maize.

Time of nitrogen fertilizer application	BH-540 (medium maturing)		BH-660 (late maturing)	
	Yield Kg/ha	Yield advantage (kg/ha) over control	Yield Kg/ha	Yield advantage (kg/ha) over control
1/2 at planting + 1/2 at knee height	6902.6	0.0	7885.8	0.0
All at planting	6462.8	-439.8	7355.1	-530.7
1/2 at planting + 1/2 at near tasseling	6178.7	-723.9	7704.7	-181.1
1/3 at planting + 1/3 at knee height + 1/3 at near tasseling	7361.2	458.6	8094.8	209.0
1/3 at planting + 2/3 at knee height	7908.0	1005.4	8095.6	209.8
1/3 at planting + 2/3 at near tasseling	7327.0	424.4	7808.9	-76.9
1/4 at planting + 2/4 at knee height + 1/4 at near tasseling	7255.1	352.5	8007.9	122.1
1/4 at planting + 1/4 at knee height+ 2/4 at near tasseling	7261.8	359.2	7981.7	95.9
1/4 at planting + 3/4 at knee height	6901.3	-1.3	8182.0	296.2
1/4 at planting + 3/4 at near tasseling	6395.6	-507	7490.8	-395.0
CV%	12.10		9.61	
$LSD_{5\%}$	990.9		NS	

maturing variety, BH 540, nitrogen application of 1/3 at planting and 2/3 at knee height gave a monitory advantage of Ethiopian Birr 651.5 over the farmers' practice of nitrogen application of 1/2 at planting and 1/2 at knee height. Similarly for the late maturing variety, BH 660, nitrogen application of 1/4 at planting and 3/4 at knee height gave a monitory advantage of Ethiopian Birr 191.9 over the farmers' practice. The Nitrogen Use Efficiency (NUE), comparison which was expressed as grain production per unit of N applied indicated that the medium maturing variety BH-540 had the highest NUE when the nitrogen was applied in split of 1/3 at planting and 2/3 at knee height (Table 6). In the case of the late maturing BH-660 variety, the highest NUE was observed when the nitrogen was split applied 1/4 at planting and 3/4 at knee height (Table 6).

DISCUSSION

In northwest Ethiopia maize is produced in a cropping season where high amount and intensity of rainfall are prevailing. In high rainfall situation leaching (loss of nitrogen) is unavoidable. Excessive rainfall after planting often results in N loss through denitrification and leaching (Thomison *et al.*, 2004).The leaching loss is also causing a reduced nitrogen nutrient use efficiency of the maize production system and in turn a reduced grain yield production. Leaching of NO_3-N is economically and envir-

Table 3. The effect of nitrogen fertilizer application time on plant height and thousand seeds weight of maize.

Time of nitrogen fertilizer application	Plant height (cm)		Thousand seeds weight (g)	
	BH-540	BH-660	BH-540	BH-660
1/2 at planting + 1/2 at knee height	293.8	343.2	336.8	350.2
All at planting	282.8	341.3	342.1	356.6
1/2 at planting + 1/2 at near tasseling	272.8	326.3	332.5	325.1
1/3 at planting + 1/3 at knee height + 1/3 at near tasseling	284.1	335.5	346.4	336.3
1/3 at planting + 2/3 at knee height	299.9	339.5	354.2	344.8
1/3 at planting + 2/3 at near tasseling	264.8	326.9	333.6	329.8
1/4 at planting + 2/4 at knee height + 1/4 at near tasseling	282.7	338.2	327.7	343.4
1/4 at planting + 1/4 at knee height+ 2/4 at near tasseling	278.7	328.3	330.6	340.6
1/4 at planting + 3/4 at knee height	284.3	333.5	341.1	331.3
1/4 at planting + 3/4 at near tasseling	258.2	312.7	337.9	329.3
CV%	4.51	3.88	5.09	4.97
LSD $_{5\%}$	14.8	15.1	NS	21.98

Table 4. Economic analysis for split application of nitrogen fertilizer using BH-540 variety.

Time of nitrogen fertilizer application	Adjusted Grain yield (kg/ha)	Man power for fer appn	Labour cost for fer appn	Gross benefit (Ethiopian Birr/ha)	Net benefit (Ethiopian Birr/ha)
1/2p+1/2k	6212.3	20	300	18637	18337
All p	5816.5	10	150	17450	17300
1/2p+1/2t	5560.8	20	300	16682	16382
1/3 p+ 1/3 k+ 1/3 t	6625.1	30	450	19875	19425
1/3 p+ 2/3 k	7117.2	20	300	21352	21052
1/3 p+ 2/3 t	6594.3	20	300	19783	19483
1/4 p+ 2/4 k+ 1/4 t	6529.6	30	450	19589	19139
1/4 p+ 1/4 k+ 2/4 t	6535.6	30	450	19607	19157
1/4 p+ 3/4 k	6211.2	20	300	18634	18334
1/4 p+ 3/4 t	5756.0	20	300	17268	16968

onmentally undesirable. Nitrate that leaches below the crop rooting zone represents the loss of a valuable plant nutrient, and hence an economic cost to agriculture. Given also the relatively high cost of fertilizer compared with produce, efficient use of N fertilizer is of both agro-economic and environmental importance (Nyamangara *et al.*, 2003). Appropriate amount of nitrogen splitting and time of application is imperative for achieving higher yield and better economic advantage for maize production in northwest Ethiopia. Recommended amounts of fertilizer should be applied in balanced proportion and at appropriate times, so that the plants can absorb these nutrients efficiently and produce maximum yield. In northwest Ethiopia, many small farmers fail to meet the above requirements and therefore, harvest low maize yields. Inappropriate time and split of nitrogen fertilizer application might have played a role in lowering the yield through reduction in fertilizer use efficiency. In the present investigation a yield increment was obtained with two split applications for both varieties. This finding is in line with the findings of numerous authors who advised two split applications for maize production (Thomison *et al.*, 2004). Similar to the present finding, from their experiment on maize, Tabu et al. (2006) recommended

Table 5. Economic analysis for split application of nitrogen fertilizer using BH-660 variety.

Time of nitrogen fertilizer application	Adjusted Gy (kg/ha)	Man power for fer appn	TVC (Labour cost for fer appn)	Gross benefit (Ethiopian Birr/ha)	Net benefit (Ethiopian Birr/ha)
1/2p+1/2k	7097.2	20	300	21292	20992
All p	6619.6	10	150	19859	19709
1/2p+1/2t	6934.2	20	300	20803	20503
1/3 p+ 1/3 k+ 1/3 t	7285.3	30	450	21856	21406
1/3 p+ 2/3 k	7286.0	20	300	21858	21558
1/3 p+ 2/3 t	7028.0	20	300	21084	20784
1/4 p+ 2/4 k+ 1/4 t	7207.1	30	450	21621	21171
1/4 p+ 1/4 k+ 2/4 t	7183.5	30	450	21551	21101
1/4 p+ 3/4 k	7363.8	20	300	22091	21791
1/4 p+ 3/4 t	6741.7	20	300	20225	19925

Table 6. Agronomic Nitrogen Use Efficiency (NUE) of the two varieties (BH-540 and BH-660)

Time of nitrogen fertilizer application	BH-540	BH-660
1/2 at planting + 1/2 at knee height	53.9	61.6
All at planting	50.5	57.5
1/2 at planting + 1/2 at near tasseling	48.3	60.2
1/3 at planting + 1/3 at knee height + 1/3 at near tasseling	57.5	63.2
1/3 at planting + 2/3 at knee height	**61.8**	63.2
1/3 at planting + 2/3 at near tasseling	57.2	61.0
1/4 at planting + 2/4 at knee height + 1/4 at near tasseling	56.7	62.6
1/4 at planting + 1/4 at knee height+ 2/4 at near tasseling	56.7	62.4
1/4 at planting + 3/4 at knee height	53.9	**63.9**
1/4 at planting + 3/4 at near tasseling	50.0	58.5

that one third of the N rate should be applied at planting while the rest top dressed eight weeks after emergence. In contrast to the split application recommendations, there are still reports that state there is no need of splitting the nitrogen and the whole fertilizer could be applied once. However, most of the investigations on nitrogen fertilizer application management are in favor of split applications which is said to synchronize timing of fertilization according to the crop demand which can increase crop grain yield (Gehl *et al.*, 2005). Though many investigations are recommending two split applications there is still variation in the proportion and timing of the N fertilizer at each applications. There are a number of reports which are recommending three and four times split applications for maize production (Sitthaphanit *et al.*, 2010). According to the findings of Muthukumar *et al*. (2007) higher values of maize yields were obtained with ½ basal + ¼ at 25DAS +1/4 at 45DAS N application. The present study showed that for the medium maturing variety, it was observed that 1/3 of the N should be applied at planting and the remaining 2/3 at knee height. However; for the late maturing variety, it was found better to apply 1/4 of the N at planting and the remaining 3/4 at knee height. This finding is slightly varied from the findings of Tolessa *et al.* (2002) who from their experiment in other part of the country recommended that 50% of the total nitrogen requirement should be applied at sowing and the remaining 50% as top dressing at knee height. It is therefore justifiable to conclude that there should be location specific nitrogen fertilizer application timing. The report of Oikeh *et al.*, (1998) demonstrated well that split recommendations for maize production could vary with environmental conditions. Their results showed that a split application of N at planting and 4 weeks after planting (WAP) appeared to be the best for Ikenne, while the entire application at 2WAP appeared to be the best in savanna ecologies. It can be concluded that it is wise to have specific nitrogen fertilizer application time recommendations for different maize growing areas. The present nitrogen split application recommendation could be used for maize growing areas which have similar amount of recommended fertilizer vis-à-vis soil and climatic condition with that of northwestern Ethiopia. Apart from the grain yield increment advantage, the N split application recommendation was found to be economically advantageous. It was observed that application of 1/3 N at planting and the remaining 2/3 at knee height for the medium maturing; and application of 1/4 N at planting and the 3/4 at knee height for the late maturing varieties were economically beneficial than other split applications for both varieties. The present conclusion about the economic profitability of nitrogen fertilizer split application is in line with a number of reports (Nyamangara *et al.*, 2003; Sitthaphanit *et al.*, 2010).The split application is also found to enhance the agronomic Nutrient Use Efficiency (NUE), which is expressed as grain production per unit of N applied, of the maize crop. Similar to this finding numerous findings reported increase in NUE with split applications (Hatfield and Prueger, 2004; Gehl *et al.*, 2005). It was further elaborated by Ahrens *et al.*, (2010) that improvement in Nitrogen use efficiency is a key issue for sustainable and profitable nitrogen use in high-input agriculture. Overall, the NUE has increased due to improved agronomic management, for example, split application (Hatfield and Prueger, 2004). The observed NUE difference among the two varieties and nitrogen split applications in the study is in agreement with the reports of Ahrens *et al.*, (2010) and Hatfield and Prueger (2004), who indicated that agronomic practices and genotypes variability can affect NUE.

CONCLUSIONS

For the medium maturing BH-540 maize variety, it was found that nitrogen should be applied 1/3 at planting and 2/3 at knee height. Similarly in the case of the late maturing BH-660 maize variety it was found better to apply nitrogen 1/4 at planting and 3/4 at knee height. The specified split application timing and proportions were found to produce high yielding, economic profits and with better NUE for the respective varieties. The current nitrogen split application recommendations could be used for maize growing areas with similar amounts of recommended fertilizer vis-à-vis soil and climatic conditions with those of the northwestern Ethiopia.

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REFERENCES

Abebayehu A, Eyasu E, Diels J (2011). Comparative Analysis of Soil Nutrient Balance at Farm Level: A case Study in Jimma Zone, Ethiopia. *Inter. J. Soil Sci*. 6.(4). pp. 259-266.

Abd El-Lattief EA (2011). Nitrogen management Effect on the Production of Two Sweet Sorghum Cultivars under Arid Regions Conditions. *Asian.J.Crop. Sci*. 3. (2). Pp.77-84.

Ahrens TD, Lobell DB, Ortiz-monasterio JI, Li Y, Matson PA (2010). Narrowing the agronomic yield gap with improved nitrogen use efficiency: a modeling approach. *Ecol. Appl.20. (1). Pp.91–100*.

Alelign K, Regassa E (1992). Bahir-Dar Mixed Farming Zone: Diagnostic Survey Report. Research Report No 18. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Buah SSJ, Mwinkaara S (2009). Response of Sorghum to Nitrogen fertilizer and Plant density in the Guinea savanna Zone. *J.Agron.* 8. (4). Pp.124-130.

CIMMYT (1988). From agronomic data to farmer recomendations: An economic training manual. Revised Edition. Mexico, D.F.

CSA. (2003). Ethiopian Agricultural Sample Enumeration, 2001/02 (1994 E.C). Central Statistics Authority, Addis Ababa, Ethiopia.

Gehl RJ, Schmidt JP, Maddux LD, Gordon WB (2005). Corn yield response to nitrogen rate and timing in sandy irrigated soils. *Agron. J.(97). Pp. 1230-1238*.

Hatfield, Prueger JH. (2004).Nitrogen Over-use, Under-use, and Efficiency. "New directions for a diverse planet". Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia. Pp 21-29.

Hefny M, Aly AA. 2008. Yielding Ability and Nitrogen Use Efficiency in Maize Inbred Lines and Their Crosses. *International J.Agric. Res.* 3.(1). Pp.27-39.

Khalily M, Moghaddam M, Kanouni H, Asheri E (2010). Disections of Drought Stress as a Grain Production Constraint of Maize in Iran. *Asian. J. Crop Sci*.2. (2). Pp.60-69.

Masaka J (2006). The Effect of N Fertilizer Placement and Timing on the Aboveground Biometric Characteristics of Spring Wheat (*Triticum aestivum* L.) on Leached Chernozem. *Inter. J. Agric. Res*.11.(1). Pp. 68-75.

Muthukumar VB, Velayudham K, Thavaprakaash N (2007). Plant Growth Regulators and Split Application of Nitrogen Improves the Quality Parameters and Green Cob Yield of Baby Corn (*Zea mays* L.). *J. Agron.* 6. (1). Pp. 2008-2011.

Nyamangara J, Bergström LF, Piha MI, Giller KE (2003). Fertilizer Use Efficiency and Nitrate Leaching in a Tropical Sandy Soil. *J. Environ. Qual.* (32). Pp. 599-606.

Oikeh SO, Kling JG, Okoruwa AE (1998). Nitrogen Fertilizer Management Effects on Maize Grain Quality in the West African Moist Savanna. *Crop. Sci.(38). Pp.1056–1061*.

Onasanya RO, Aiyelari OP, Onasanya A, Nwilene FE, Oyelakin OO (2009). Effect of Different Levels of Nitrogen and Phosphorous Fertilizers on the Growth and Yield of Maize (*Zea mays* L.) in Southwest Nigeria. *Inter. J. Agric. Res*. 4. (6). pp. 193-203.

SAS Institute (2002). Users guide, basic version 9.1 Edition. Carry, NC: SAS Institute, USA.

Sitthaphanit S, Limpinuntana V, Toomsan B, Panchaban S, W Bell R (2010). Growth and Yield Responses in Maize to Split and Delayed Fertilizer Applications on Sandy Soils under High Rainfall Regimes. *Kasetsart J. (Nat. Sci.) (44). pp. 991 – 1003*.

Tabu IM, Obura RK, Bationo A, Mumera L (2006). Effect of Fertility Management and Nitrogen Fertilizer Rate on Maize Yield in Small Holder farmers Fields. *J.Agrono.* 5. (2). pp.191-195.

Thomison PR,Geyer AB, Bishop BL, Young JR , Lentz E (2004). Nitrogen fertility effects on grain yield, protein, and oil of corn hybrids with enhanced grain quality traits. Plant Management Network. Accepted for publication 15 October 2004. Published 24 November 2004.

Tolessa D, Gemechu G, Melakeselam L (1994). Response of Maize to Split Application of Nitrogen Fertilizer at Bako. In: CSSE (Crop Science Society of Ethiopia). 1995. Sebil. Vol.6. Proceedings of the Sixth Annual Conference. 3-4 May 1994, Addis Abeba, Ethiopia. pp. 56-60.

Tolessa D, Tesfa B, Wakene N, Tenaw W, Minale L, Tewodros M, Birtukan M , Waga M (2002). A review of fertilizer management research on maize in Ethiopia. Enhancing the Contribution of Maize to Food Security in Ethiopia: Proceedings of the Second National Maize Workshop of Ethiopia, 12-16 November 2001, Addis Ababa, Ethiopia: Ethiopian Agricultural Research Organization (EARO) and International Maize and Wheat Improvement Center (CIMMYT).

UNDP (1996). Sustainable Agricultural and Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey of the Amhara Region. Vol.1. Produced by the Cooperative Endeavors of the Amhara Regional Council. Bahir Dar, Ethiopia.

Wondesen T, Sheleme B (2011). Identification of Growth Limiting Nutrients in Alfisols: Soil Physico-chemical Properties, Nutrient Consentrations and Biomass Yield of Maize. *Ame. J.Plant. Nutri. Fertili. Technolo.* 1. (1). pp. 23-35.