**The Effect of Fertilizer Micro-dosing Rates on Yield Performance of Maize at Loka Abaya District, Southern Ethiopia**

**Abstract**

*Optimizing fertilizer use is the most important route to increasing soil productivity. However, maintenance of soil fertility poses a pressing challenge in smallholder due for inefficiency in the returns of inputs, inefficient application methods and management committed to their farms. Mostly fertilizer use is limited due to high cost. ~~In order~~ To get the maximum benefit from fertilizer application, it should be applied with the proper rate and methods. There was no scientific information available with regards to the response of maize to fertilizer micro-dosing technology in the study area. The study was undertaken to determine the effect of nitrogen and phosphorus fertilizer dozing on yield improvement of maize during 2016/2017 and 2017/2018 cropping seasons on farmer’s fields. Five treatments tested were: control, micro-dosing treatments (50, 75, and 100% of the recommended dose of Nitrogen (92 N) and Phosphorus (69 P2O5) and 100% of recommended NP by the banding methods that arranged in randomized complete block design replicated three times. The analysis of variance indicated that application methods with different rates of fertilizer revealed significant effect on growth and yield components. Application of 92 N + 69 P2O5 by banding was resulted in significantly higher results of plant height, cob length, hundred kernel weight, stover and grain yield over application of 46 N + 34.5 P2O5 by micro-dosing and control but statistically at par with application of 69N + 51.75 P2O5 and 92 N + 69 P2O5 by the micro-dose method. Given the* ***low soil fertility*** *in the study area, the soil responded well to the* ***maximum amount of fertilizer*** *regardless of the application method used.*

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*Moreover, the treatment improved grain yield by 58.7% over the control. The applied treatments improved nutrient concentration, uptake and recovery of maize over Control. Therefore, the application of 100% rNP by banding can be recommended for maximum maize production in Loka Abaya and similar agro-ecological areas with low soil fertility.*

**Key words**: Banding, micro-dosing, nutrient uptake, recommended NP, recovery

**Introduction**

In Ethiopia, maize is an important food crop because of its high productivity per unit area, suitability to major agro ecologies, compatibility with many cropping systems, and ease of traditional dish preparation. It is also a food security crop in the country where recurrent drought is a common phenomenon [1] (Bogale *et al.,* 2002). Maize grows best in deep and well-drained loamy soils but can be cultivated nearly anywhere in the country.

Soil degradation is a serious problem in many parts of Ethiopia largely as a result of mismanagement of the natural resource base [2] (Debelle *et al.,* 2002). In small-holder mixed farming systems, loss of soil fertility results from excessive nutrient mining through crop harvest without adequate replenishment. Maintenance of soil fertility poses a pressing challenge for smallholder due to low returns of inputs, inefficient application methods, and poor management committed to their farms. Proper fertilization is most important issue that needs to be addressed in crop production to enhance nutrient use efficiency and maintain soil fertility. Low soil fertility is one of the biggest challenges to maize production in Ethiopia [2] (Debelle et al., 2002).

Maize is a heavy nutrient feeder [3] (Onasanya *et al.,* 2009) and has high demand for N and P which are the most limiting nutrients [4] (Nigussie *et al.,* 2002) while they are very essential for good vegetative growth and grain development in maize production. The easiest way to increase soil N and P is the addition of inorganic nutrients, such as urea and di-ammonium phosphate (DAP) or NPS with the available fertilizer application methods that use high fertilizer rates [2] (Debelle *et al.,* 2002). This is rather expensive for the small-holder farmers who is usually resource constrained. Although the routes to increasing soil productivity include optimizing fertilizer use, prevailing fertilizer recommendations are high and beyond the reach of most smallholder farmers.

In Ethiopia, the predominant methods for applying fertilizer are broadcasting, top dressing, and banding. There is no documentation on the use of fertilizer micro-dosing. National research institutes primarily recommend the banding method, while farmers use the broadcasting method for broadcasted crops and banding for row-planted crops [5] (Sime and Aune, 2014). However, the effect of fertilizers is minimal, due to applications being below the recommended rates, and the failure to use DAP and Urea in proper combinations. Hence, there is a need for alternative lower but more efficient and cost-effective fertilizer recommendations. Micro-dosing fertilizer can significantly boost fertilizer efficiency and increase crop yields. This method also helps reduce input costs and improves the return on investment [6] (Endale, 2010).

Therefore integrated use of appropriate fertilizer application and fertilizer rate is an alternative measure to alleviate soil fertility and enhance yield in sustainable production systems. Although most of the mid altitude of the zone is suitable for maize production, the productivity by using microdose fertilizer application is limited mainly due to lack of information on the technology in the specified area. Therefore the following study was conducted with the objective of evaluating the effect of micro-dose application of fertilizer on yield and yield component of maize.

**Materials and Methods**

**Description of the Study Area**

The study was conducted during the 2016/17 and 2017/2018 main cropping season at Loka Abaya district dese kebele, SNNPR on farmers**’** fields to evaluate the effect of micro-dose fertilizer application on yield performance of maize. The research site is situated at 6º 43′16.3” N and 38º 18′34” E latitude and longitude, respectively and at an altitude of 1620 m.a.s.l. There are two overlapping seasons for crop production in the study site. The first season usually extends from April to September, while the second season, which is the main rainy season, extends from June to October. July and August are the wettest months. Mid-maturing maize is the main crop for the first (and longer) season. The weather data of the site (Figure 1) was obtained from the Southern Region Meteorological Agency. In 2017 and 2018 cropping seasons, the area received annual rainfall of 1824.4 and 1132 mm, respectively. The annual mean maximum temperatures over the two years were 28.12 and 27.2 0C while the mean minimum temperatures were 8.2 and 7.40C, respectively. The mean rainfall of the two cropping seasons showed a similar pattern with the mean long-term average of 1263.07 mm per annum but the amount in 2017 was higher than the long-term average and lower in 2018.

Figure 1. Mean monthly rainfall and temperature during crops growth period (2017-2018)

**Treatments and Experimental Design**

The experiment had five levels of treatment *viz* control (0 fertilizer), 46 N + 34.5 P2O5 by micro-dosing, 69 N + 49.5 P2O5 by micro-dosing, 92 N + 69 P2O5 by micro-dosing and 92 N + 69 P2O5 by banding method. DAP was used as a source of N and P, while urea was used as an additional source of N. The whole doses of DAP and 1/3 of urea were applied at planting time while the remaining 2/3 of urea was top dressed at knee height. The treatments were arranged in randomized complete block design (RCBD) with three replications having a net plot size of 3.3 x3.75 m. Hybrid variety of maize namely BH-540 which is high yielding and adapted to the agro-ecology of the area was sown during mid-May with spacing of 75cm between rows and 30 cm between plants. Pathways between blocks and plots were 1m and 0.5m, respectively. Each row and plot had 11 and 55 plants of maize, respectively per plot. The experimental field was managed using the standard maize cultivation practices recommended for this area.

**Soil and Plant Sampling and Analysis**

Surface layer soil samples (0 - 20 cm depth) were collected in a zigzag way from 13 random points to make one composite sample before planting during both seasons. The samples were air-dried, grounded, and passed through a 2 mm sieve to remove large particles, debris, and stones, except for the analysis of organic carbon and nitrogen, where the samples were passed through a 0.5 mm sieve. The samples were analyzed for soil texture, pH, organic carbon, organic matter, total N, available phosphorus and exchangeable cation at Soil and Water Analysis Laboratory, Horticoop Ethiopia PLC. Particle size distribution (texture) was determined by the hydrometer method using particles less than 2 mm diameter [7] (FAO, 2008). The pH of the soil was determined using a pH meter with combined glass electrode in water (H2O) at 1:2.5 soils: water ratio as described by [8] Carter (2007). Soil organic carbon content was determined using the Walkley and Black method (1934). This method involves the reduction of potassium dichromate by organic carbon compounds, followed by an oxidation-reduction titration with ferrous ammonium sulfate). Total N in the soil was determined by the Kjeldahl method [10] (Dewis and Freitas, 1975) and available P and Exchangeable cation (K+) was determined following Mehlich-3 extraction method as described by [11]Mehlich (1984).

Representative plant samples were collected both from grain and vegetative parts of maize after harvest and analyzed for the determinations of nutrient (N and P) concentrations. The measurement of NP nutrients was determined by wet digestion method. Analyzed were done in the nitrogen (N) and phosphorus (P) concentrations to determine their uptake in both the grain and stover. This data then allowed us to calculate the N and P fertilizer recoveries. Nutrients both N and P uptake in the stover and grain were calculated by multiplying nutrients concentration by the total biomass weight of stover and grain.

Stover/ Grain Nutrient uptake (kg/ha) = Nutrient concentration in stover/ grain (%) \* total stover/ grain dry weight (kg/ha)/100. Whereas, apparent nutrient recovery or fertilizer recovery (FR)was calculated as, the total uptake (TU) of each fertilized treatment minus total uptake (TU) of nutrient due to nutrient omission divided by the rate of fertilizer added. It was calculated by the following equation from [12] Vanlauwe *et al.* (2001).

**Data Collection and Analysis**

Data collection started two weeks after the treatments were applied. Five plants were randomly selected from each plot at maturity for recording plant height, leaf area and cob length. At harvest, all plants avoiding boarder were harvested, air dried, and manually threshed to determine straw, grain and total biomass yields per plot, which were later converted to yields per hectare. Grain yields were adjusted to l2% moisture content. Analyses of variances for the data were conducted using Proc Mixed Procedure with SAS software version 9.0 [13] (SAS, 2002) to determine the treatment effects. The significance difference between any two treatments mean was tested by least significant difference (LSD) at 5% probability level used for mean separation.

**Results and Discussion**

**Physical and Chemical Properties of the Experimental Soil before Planting**

The experimental soil was loam in texture with particle size distribution of 30 % sand, 48 % silt and 22% clay indicating that silt was the most dominant fraction in the soils (Table 1) which is a good textural class for maize [2] (Debelle *et al.,* 2002). The soil was moderately alkaline with a pH of 6.95 [14] (Jones, 2003). This values falls in the pH range that is very conducive for maize production as normal soil pH for maize is recorded to be from 5-8, a pH of 6-7 probably being an optimal for most varieties [15] (Martin, 1993).The organic carbon content is 1.54 % whereas; total nitrogen content is 0.11 %. Both parameters qualify for low range according to with [16] Landon (1991). An available (Mehlich-3 extractable) P of the soil was 17.33 mg kg-1 which was low [17] (Mylavarapu *et al.,* 2014).

Table 1. Physicochemical properties of soil before planting

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Soil properties | | | | | | | | | | |
| Location | % sand | % silt | % clay | STC | pH | TN (%) | OC (%) | SOM (%) | Av.p (mg kg-1) | K+ (mg kg-1) |
| Loka Abaya | 30 | 48 | 22 | Loam | 6.95 | 0.11 | 1.54 | 2.655 | 17.33 | 232.06 |

**Effect of Fertilizer Micro-dosing and Banding Fertilizer Application on Maize Growth Parameters**

In both cropping seasons, maize germination did not show significant (*p≤0.05*) response to fertilizer rates and application methods (Table 2). The result also showed that applied treatments significantly (*p≤0.05*) affected Plant height. The tallest mean plant height (2.56 m) was noticed when 100 % rNP applied by banding though it was statistically similar to application of 75 and 100 % rNP by micro-dosing method. Banding of 100% rNP increased plant height of maize by 14.5 % over micro-dosing of 50% rNP and 34 % over Control. All fertilizer rates significantly improved plant height over control. The shortest plant height (1.69 m) was recorded from unfertilized plot. Nitrogen being the major constituent of chlorophyll, whose intensity is known to increase with added nitrogen supply, might have promoted the plant growth of maize [18] (Naik *et al.,* 2017). Increase in plant height with nitrogen and phosphorus application has been reported by [19] (Ayub *et al.,* 2002 and [20]Cheema, 2000). [21]Law-Ogbomo and Law-Ogbomo. (2009) also reported that, plant height of maize was increased with successive increment in NPK fertilizer application rate up to 600 kg ha-1.

**Table 2. Effect of fertilizer micro-dosing and banding methods on growth parameters of maize**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Germination % | Plant height (m) | Leaf area (cm2) | Cob length(cm) |
| No fertilizer | 90.9 | 1.69c | 538.42b | 21.6b |
| MD of 50% rNP | 95.2 | 2.19b | 595.99ab | 24.5b |
| MD of 75 % rNP | 93.7 | 2.48a | 636.64a | 24.88ab |
| MD of 100 % rNP | 96.5 | 2.49a | 668.75a | 25.93ab |
| BD of 100 % rNP | 95.8 | 2.56a | 683.94a | 29.23a |
| CV | 6.5 | 7.3 | 12.5 | 14.3 |
| LSD | Ns |  |  |  |

*Means in a column followed by the same letters are not significantly different at p≤5% level of significance; LSD= least significant difference; CV = coefficient variation; MD= micro-dosing BD= banding, rNP= recommended nitrogen and phosphorus.*

In addition, application of 100 % rNP by banding to maize resulted in longest cob length (29.23 cm) which was significantly superior to application of 50 % rNP (24.5 cm) and Control (21.6 cm) (Table 2). It increased cob length of maize by 16.2 over micro-dosing of 50 % rNP and 26.1 % over Control. However, the result is statistically at par with application of 75 and 100% rNP by micro-dosing. Similarly, application of recommended dose of nitrogen to maize resulted in longest cob length which was comparable with that of 75 % recommended dose of nitrogen application was reported [18] (Naik et al., 2017). The significant response may probably be due to adequate supply of N which enhanced more photosynthetic activities of the plant. This is in line with the finding [22] Mukhtar et al. (2011) which prove NP rate 250-125 gave maximum cob length of maize. Characters linked to cob which were positively influenced by nitrogen fertilization were reported and this is due to N influence on division and expansion of cell and photosynthetic process with consequent better root and shoots development [23] (Okumura et al., 2011). The highest leaf area was also recorded from application of 100 % rNP by banding. However, the result was statistically similar with application of 75 and 100 % rNP by micro-dosing. In general, application of 75 and 100 % rNP by micro-dosing and 100 % rNP by banding methods were resulted with statistically not different results on all growth parameters.

**Effect of Fertilizer Micro-dosing and Banding Application on Maize Yield and Yield Components**

Stand count at harvest was significantly (*p≤0.05*) affected by applied treatments. In 2017, maximum plant stand (30.7) was noticed from 100 % rNP by banding which was statistically similar with stand count recorded from application of 75 and 100 % rNP by micro-dosing (Table 3). Increasing NP levels from 0 (Control) to 100% showed linear and consistent increment in stand count of maize ranging from 10.98 to 26.38 %. In 2018, maximum plant stand (31.33) was noticed from application of 100 % rNP by banding which was statistically similar with stand count recorded from application of 75 and 100 % rNP by micro-dosing. Number of grain per cob was significantly (*p≤0.05*) influenced by fertilizer applied over the control. Increasing NP levels showed linear and consistent increment in number of grain ranging from 25.4 to 35 % over Control. Band application of 100 % rNP produced significantly maximum number of grain (407.7). However, the result was similar for all fertilized plots. The results are in accordance with those of who reported that nitrogen and phosphorous fertilizer applications significantly affected the grains number per cob [22] (Mukhtar *et al.,* 2011).

**Table 3. Effect of fertilizer micro-dosing and banding methods on yield and yield components of maize**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment | Stand count | No of grain per cob | 100 seed weight (g) | Stover yield  (kg/ha) | Grain yield  (kg/ha) | Harvest Index |
| No fertilizer | 23.5c | 264.9b | 26.49c | 4425.8d | 2459.1d | 0.432 |
| MD of 50% rNP | 26.5b | 355.03a | 30.56b | 6382.2c | 4385.6c | 0.535 |
| MD of 75 % rNP | 29.0a | 382.8a | 33.12a | 7259.5b | 4831.6bc | 0.519 |
| MD of 100 % rNP | 29.4a | 395.6a | 33.96a | 7600.8ab | 5459.7ab | 0.534 |
| BD of 100 % rNP | 30.7a | 407.7a | 34.88a | 7928.5a | 5952.5a | 0.588 |
| CV | 6 | 11.56 | 6.4 | 5.4 | 12.9 | 26.7 |
| LSD |  |  |  |  |  | Ns |

*Means in a column followed by the same letters are not significantly different at p≤5% level of significance; LSD= least significant difference; CV = coefficient variation; MD= micro-dosing BD= banding, rNP= recommended nitrogen and phosphorus.*

The result of this study shows that application of treatments significantly (*p≤0.05*) affected hundred kernel weight (Table 3). Maximum hundred kernel weight (34.88 g) was found at banding of 100 % rNP though statistically at par with micro-dosing of 75 and 100 % rNP. Band application of 100 % rNP increased hundred kernel weight by 24 % over the Control. Maximum hundred kernel weight from application of 120kgNha-1 + 60kgPha-1 due to increase in phosphorus rate from 40 to 60kg ha-1 was reported [3] (Onasanya *et al.,* 2009). In addition, [24]Kakar *et al.* (2014) reported that 100 grain weight are regarded as the basis for final economic yield, higher nitrogen rate can promote leaf area development during vegetative development and maintaining functional leaf area during growth period may be the possible reason for photo assimilate formation and increase in grains weight

Application of treatments significantly (*p≤0.05*) affected stover yield. Maximum stover yield (7928.5kg ha-1) was observed due to band application of 100 % rNP though statistically at par with micro-dose application of 100% rNP. It also improved stover yield by 44.2 % over Control. Variance fertilizer rates improved stover yield by 30.7 to 44.2 % over Control. Increasing levels of nitrogen and phosphorus in the soil under different soil and management condition showed increased stover yield of maize [19] (Ayub *et al.,* 2002; [20] Cheema, 2000 and [25]Hani *et al.,* 2006).

Application of treatments revealed significant (*p≤0.05*) variation on grain yield of maize. All of the variable fertilizer rates were able to improve yield significantly over the control. Maximum grain yield (5952.5kg ha-1) was recorded from application of 100 % rNP by banding (Table 3). Grain yield advantage of 26.3% over micro-dosing of 50% rNP and 18.8 % over 75% rNP was observed. The increase in grain yield with the highest rate of NP fertilizer was attributed to increase in yield components like number of grain per cob and 100-kernel weight. [26] Olusegun (2015) reported significant increases in maize grain yield due to application of nitrogen to the highest dose of the study. Likewise, [27] Sarma *et al.* (2000) observed that higher grain yield of maize was obtained with the application of 120 kg N ha-1 as compared to lower levels of nitrogen. Unfertilized plot resulted in significantly lower grain yield (2459.1 kg ha-1) which is 58.7 % lower than maximum yield. However, an average maize grain yield of control plot in 2017 was close to the national average yield of maize (3.14t ha-1). The use of improved varieties, row planting and better management practices of the trial plots might have contributed to this result. As fertilizer rate increased, yield is also increased. This might be due to maize is heavy nutrient feeder and has high demand for N and P whereas the study area was low in total nitrogen and available phosphorus. These findings are in line with those of [25] Hani *et al.* (2006) and [28] Ali *et al.* (2002) who reported increase in grain yield with NP application. On the other hand, [22] Mukhtar *et al.* (2011) reported that grain yield increased up to optimum level of 250-125 kg NP beyond which it tended to decrease. In contrast to the present finding, [5] Sime and Aune, (2014) reported that maize yield decreased as fertilizer amount increase from 27 + 27 NP to 80 + 80 NP kg ha-1. The minimum grain yield was recorded from unfertilized plot in both years. Generally, most of the yield characteristics vary with fertilization and non-fertilization.

Harvest index (HI) of the maize crop was found unaffected by applied treatments during both cropping season. As a result, no significant difference was recorded among fertilized plot. However, all plots treated by fertilizer were significantly superior over the control.

**Nutrient Uptake and Recovery of Maize Stover and Grain Yield**

The maximum total N uptake (65.1 kg N ha-1) was obtained from application of 100% rNP by micro-dosing. It was evident that higher uptake of N by the crop has contributed towards the increased grain yield, which was not seen in the Control. This might be due to effect of applied fertilizer and phosphorus positive interaction. [29] Okebalama (2015) reported higher N uptake in maize stover with N120P90 compared to the other treatments in two soil types advances credence to the synergistic effect of P on maize use of N in low fertility soils. The maximum total P uptake (23.976 kg P ha-1) was recorded at band application of 100 % rNP. Both maximum P uptake in grain and stover was also recorded from application of the same treatment. This might be due to nitrogen role to increase P concentration in plants by increasing root growth, increasing the ability of roots to absorb and translocate P which directly increases the P uptake [30] (Havlin et al., 2003). N and P and their positive interaction significantly increased N uptake at all concentrations of N of maize was reported by [31] (Fosu-Mensah and Mensah, 2016).

The apparent N and P recovery increased with increasing rate of N and P fertilizers application however recovery were inconsistence (Table 4). The highest mean recoveries of N and P recorded were 65.1% and 26.8%, respectively. The maximum (65.1%) and minimum (51%) apparent recoveries of N were obtained from micro-dose application of 100 rNP and micro-dosing of 50 % rNP, respectively. In line with this finding, 65% recovery of nitrogen for maize is reported by [32] (Ladha *et al.,* 2005). The maximum (26.8%) and minimum (22.3%) apparent recoveries of P were obtained from application of 100 % rNP by banding and 100 % rNP by micro-dosing, respectively.

**Table 4. Mean grain and stover nutrient uptake of maize during 2018 cropping season**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatment | N uptake (Kg ha-1) | | | P uptake (Kg ha-1) | | | Nutrient recovery | |
| Grain | Stover | Total | Grain | Stover | Total | N | P |
| No fertilizer | 4.515 | 0.700 | 5.215 | 3.568 | 1.906 | 5.474 | - | - |
| MD of 50% rNP | 24.474 | 4.200 | 28.674 | 9.182 | 4.168 | 13.349 | 51.0 | 22.8 |
| MD of 75 % rNP | 36.752 | 8.245 | 44.997 | 13.407 | 5.668 | 19.075 | 57.7 | 26.3 |
| MD of 100 %rNP | 51.309 | 13.793 | 65.101 | 14.116 | 6.766 | 20.882 | 65.1 | 22.3 |
| BD of 100 % rNP | 48.464 | 13.426 | 61.890 | 16.920 | 7.057 | 23.976 | 61.6 | 26.8 |

Means in a column followed by the same letters are not significantly different at p≤5% level of significance; LSD= least significant difference; CV = coefficient variation; MD= micro-dosing BD= banding, rNP= recommended nitrogen and phosphorus.

The apparent N and P recovery increased with increasing rate of N and P fertilizers application however recovery were inconsistence (Table 4). The highest mean recoveries of N and P recorded were 65.1% and 26.8%, respectively. The maximum (65.1%) and minimum (51%) apparent recoveries of N were obtained at 100 and 50 % recommended NP by micro-dosing, respectively. Whereas, the maximum (26.8%) and minimum (22.3%) apparent recoveries of P were obtained at 100 % recommended NP by banding and micro-dosing, respectively.

**Conclusion**

Our two year result indicates that application methods with different rates of fertilizer revealed a significant effect on maize growth and yield components. Application of 100 % recommended NP by banding resulted in significantly higher results of growth (plant height and cob length) and yield components (hundred kernel weight, stover and grain yield) over application of 50 and 75 % recommended NP by micro-dosing but statistically at par with application of 100 % recommended NP by micro-dose method. This may be due to low soil fertility status of the study area which responds to the maximum amount of fertilizer in both application methods. Moreover, the treatment improved grain yield by 142% over the control. Therefore application of 100 % recommended NP by banding method can be recommended for maximum maize production in Loka Abaya and similar agro ecological areas with low soil fertility.

**References**

Ali J., Bakht J., Shafi M., Khan S., Shah W.A., 2002. Uptake of nitrogen as affected by various combinations of nitrogen and phosphorus. Asian Journal of Plant Science 1: 367-369.

Bogale, T., Debele, T., Gebeyehu, S., Tana, T., Geleta, N. and Workayehu, T., 2002. Development of appropriate cropping systems for various maize producing regions of Ethiopia. In 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 (pp. 61-70).

Carter, M.R. and Gregorich, E.G. eds., 2007. Soil sampling and methods of analysis. CRC press.

Cheema, H.N.A., 2000. Yield and quality response of maize (Zea mays L.) fodder grown on different levels of phosphorus and seedling densities. M. Sc.(Hons.) Thesis, Dept. Agron., Univ. Agric. Faisalabad, Pakistan.Dewis J, Freitas P. 1975. Physical and chemical methods of soil and plant analysis.

Debelle, T., Bogale, T., Negassa, W., Workayehu, T., Liben, M., Mesfin, T., Mekonnen, B. and Mazengia, W., 2002. A review of fertilizer management research on maize in Ethiopia. Enhancing the contribution of maize to food security in Ethiopia, pp.46-55.

Endale, K., 2010. Fertilizer consumption and agricultural productivity in Ethiopia. In In the Ethiopian Development Research Institute Working Papers, February 2011; Gebre-ab, N., Dorosh, P., Eds.; Ethiopian Development Research Institute (EDRI): Addis Ababa.

FAO (Food and Agriculture Organization of the United Nations). 2008. FAO fertilizer and Plant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis. FAO, Rome, Italy. 203p.

Fosu-Mensah, B.Y. and Mensah, M., 2016. The effect of phosphorus and nitrogen fertilizers on grain yield, nutrient uptake and use efficiency of two maize (Zea mays L.) varieties under rain fed condition on Haplic Lixisol in the forest-savannah transition zone of Ghana. Environmental Systems Research, 5(1), pp.1-17.

Eltelib, H.A., Hamad, M.A. and Ali, E.E., 2006. The effect of nitrogen and phosphorus fertilization on growth, yield and quality of forage maize (Zea mays L.). Journal of Agronomy.

Havlin J.L., Beaton J.D., Tisdale S.L. and Nelson W.L., 2003. “Soil fertility and fertilizers”. An introduction to nutrient management 6th ed Pearson Edu. India.

Jones J.B. 2003. Agronomic handbook: management of crops, soils, and their fertility. CRC Press LLC, Boca Raton, Florida, USA. 482.

Kakar, K.M., Khan, A., Khan, I., Shah, Z. and Hussain, Z., 2014. Growth and yield response of maize (Zea mays L.) to foliar NPK-fertilizers under moisture stress condition. Soil & Environment, 33(2).

Ayub M, Nadeem M A, Sharar M S, Mahmood N. 2002. Response of maize (Zea mays L.) fodder to different levels of nitrogen and phosphorus. Asian J. plant sci., 1: 352-254.

Ladha, J.K., Pathak, H., Krupnik, T.J., Six, J. and van Kessel, C., 2005. Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. Advances in agronomy, 87, pp.85-156..

Landon J.R. 1991. “Booker tropical soil manual, a hand book for soil survey and agricultural land evaluation in the tropics and subtropics,” Longman, Booker. 474p.

Law-Ogbomo, K.E. and LAW-OGBOMO, J.E., 2009. The performance of Zea mays as influenced by NPK fertilizer application. Notulae Scientia Biologicae, 1(1), pp.59-62.

Mehlich A. 1984. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. Communications in soil science and plant analysis, 15:1409-1416.

Mukhtar, T., Arif, M., Hussain, S., Tariq, M. and Mehmood, K., 2011. Effect of different rates of nitrogen and phosphorus fertilizers on growth and yield of maize. Journal of Agricultural Research, 49(3), pp.333-339.

Mylavarapu, R., Obreza, T., Morgan, K., Hochmuth, G., Nair, V. and Wright, A., 2014. Extraction of soil nutrients using Mehlich-3 reagent for acid-mineral soils of Florida. Nutrient Management of Vegetable and Row Crops Handbook, pp.1-7.

Naik, M.S.P., Sumathi, V. and Kadiri, L., 2017. Response of optimum nitrogen rate in maize with legume intercropping system. SAARC Journal of Agriculture, 15(1), pp.139-148.

Nigussie, M., Tanner, D. and Twumasi-Afriyie, S. eds., 2002. 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. CIMMYT.

Okebalama, C.B., 2015. Impact of targeted nitrogen and phosphorus fertilizer micro-dosing on maize and cowpea yields under two cropping systems (Doctoral dissertation).

Okumura R.S., Takahashi H.W., Santos D.G.C., Lobato A.K.S., Mariano D.C., Marques O.J., Silva M.H.L.S., Neto C.F.O. and Lima Junior J.A. 2011. Influence of different nitrogen levels on growth and production parameters in maize plants. Journal of Food, Agriculture & Environment Vol.9 (3&4): 510-514. [www.world-food.net](http://www.world-food.net)

Olusegun, O.S., 2015. Nitrogen (N) and phosphorus (P) fertilizer application on maize (Zea mays L.) growth and yield at Ado-Ekiti, South-West, Nigeria. Journal of Experimental Agriculture International, pp.22-29.

Onasanya, R.O., Aiyelari, O.P., Onasanya, A., Oikeh, S., Nwilene, F.E. and Oyelakin, O.O., 2009. Growth and yield response of maize (Zea mays L.) to different rates of nitrogen and phosphorus fertilizers in southern Nigeria. World Journal of Agricultural Sciences, 5(4), pp.400-407.

Sarma, N.N., Paul, S.R. and Sarma, D., 2000. Response of maize (Zea mays) to nitrogen and phosphorus under rainfed conditions of the hills zone of Assam. Indian Journal of Agronomy, 45(1), pp.128-131.

SAS, 2002 version 9.0 Institute Inc., Cary, NC, USA.

Sime, G. and Aune, J.B., 2014. Maize response to fertilizer dosing at three sites in the Central Rift Valley of Ethiopia. Agronomy, 4(3), pp.436-451.

Vanlauwe, B., Aihou, K., Aman, S., Iwuafor, E.N., Tossah, B.K., Diels, J., Sanginga, N., Lyasse, O., Merckx, R. and Deckers, J., 2001. Maize yield as affected by organic inputs and urea in the West African moist savanna. Agronomy journal, 93(6), pp.1191-1199.

Walkley, A. and Black, I.A., 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science, 37(1), pp.29-38.