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Effects of integrated nutrient application on phenological, vegetative growth and yield-related parameters of maize in Ethiopia: A review

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Abstract: Declining soil fertility was the major factor for lower productivity of maize and to combat these problems, commercial fertilizers have been applied. However, rising costs of inorganic fertilizers may not encourage the smallholder farmers. Therefore, in sourcing for an alternative that reduces the cost of production while increasing the productivity, integrated soil fertility management has been recommended. Several research attempts have been made to optimize the integrated uses of organic and inorganic fertilizers at different locations. An experiment conducted in Bako concluded use of 12 t ha^{-1} of FYM with 28/12 NP_2O_5 kg ha^{-1} saved up to 75% cost of commercial fertilizer. A trial at Wolaita recommended combined use of compost (5 t ha^{-1}) with 50 kg urea and 100 kg DAP ha^{-1}. Another field experiment conducted in Western Oromiya, application of 150/50 kg ha^{-1} of the Urea and DAP with 4 t FYM ha^{-1} was recommended for sustainable production of maize. An experiment conducted at Wujiraba concluded better yield and quality obtained with the application of 120 kg N and 15 kg S ha^{-1} with 10 t ha^{-1}of compost. Another trial conducted on an acidic nitosol of Southwestern Ethiopia concluded application of 50% recommended NP and 50% compost gave the highest grain yield. A field experiment at Wolaita also indicated, using compost at 5 t ha^{-1} fortified with urea is

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PUBLIC INTEREST STATEMENT

Maize is one of the small cereals widely grown in Ethiopia. It is produced under rainfed and irrigation production systems both by smallholder farmers and organized farms. Since maize is widely utilized as food, animal fodder and source of fuel by the people in Ethiopia, its popularity is much higher than other cereals crops. Despite the multifaceted importance of the crop, its current production is constrained by various problems. Inappropriate agronomic practices are among other main problems associated with low productivity and quality of maize produced in Ethiopia. Thus, the development of location-specific agronomic practices such as fertility management, spacing, hoeing and weed control, are necessary to boost the productivity of maize and thus alleviate food insecurity to smallholder producers. It will also enhance the expansion of maize production in the country.

better. Another work done at Ebantu showed that combination of vermicompost at 2.5 t ha^{-1} and mineral P fertilizer (20 kg ha^{-1}) with lime (4 t ha^{-1}) was optimum.

Subjects: Agriculture & Environmental Sciences; Botany; Agronomy

Keywords: Integrated nutrient; maize; yield; Ethiopia

1. Introduction

Maize (*Zea mays* L.) is a member of the *Gramineae* family. It originated in America and was first cultivated in the area of Mexico more than 7,000 years ago (Hilaire, 2000). In the world production, maize is ranked as the third major cereal crop after wheat and rice (Zamir et al., 2013). It is widely grown in tropical, subtropical and temperate regions of the world throughout the year mainly due to its photo-thermo-insensitive character (Kumar Verma, 2013). It is a primary staple food crop in many developing countries (Kandil, 2013).

World production of maize is with an area of more than 118 million hectares with an annual production of about 6 million metric tons (Farhad, Saleem, Cheema, & Hammad, 2009). In 2014, United States topped the list of 10 maize producing countries which includes China, Brazil, EU-27, Ukraine, Argentina, India, Mexico, South Africa and Canada with an amount of about 351 million metric tons (Mitiku & Asnakech, 2016). Among the developing countries, maize production has a paramount importance in Africa. The main maize producers in Africa include Kenya, Tanzania, Zambia and Zimbabwe (Mitiku & Asnakech, 2016).

Ethiopia is the fifth largest producer of maize in Africa and smallholder farmers make up 94% of the crop production (Mitiku & Asnakech, 2016). Maize is cultivated in a wide range of altitudes, moisture regimes, soil types and terrains, mainly by smallholder crop producers. It is mainly produced in southern, western, central and eastern regions of Ethiopia (Ministry of agriculture and Rural Development [MoARD], 2009). The mid-altitude, sub-humid agro-ecology (1,000–1,800 m.a.s.l.) is the most important maize producing environment in Ethiopia (Wende, 2013). According to the Central Statistical Agency [CSA] (2013b) reports of the year 2013 main cropping season, out of the total grain crop areas of 9.60×10^6 ha, maize accounts for 16% (~2.01×10^6 ha) area coverage with annual production of 6.1 million tons and an average yield of 2.24 t ha^{-1} which is far below the global average yield of 4.9 t ha^{-1} (Edgerton Michael, 2009). This low productivity of maize is mainly attributed to many factors including frequent occurrence of drought, declining soil fertility (International Food Policy Research Institute [IFPRI], 2010), poor agronomic practice, limited use of inputs, poor seed quality, diseases and pests occurrence (Wende, 2013). Among these, declining soil fertility, due to continuous cultivation with low input is a major limitation to crop production and productivity in smallholder farms in Ethiopia (Mosisa Worku et al., 2012).

In Ethiopia, maize production is done on 2,135,571.85 ha with the productivity of 3.675 t ha^{-1} involving about 10,862,725 smallholder farmers almost in all regions of the country dominantly producing maize (CSA, 2011). In terms of regional distribution, 41.9% of the producers are found in Oromia, 28.6% in Amhara, 18.7% in South Nation, Nationality and People's Region (SNNP), 6.9% in Tigray, and 2.4% in Benishangul Gumuz Regional States (CSA, 2013a). Farm size considerably varies from less than 0.5 ha to over 10 ha and almost 72% of the maize producers own less than 2 ha. The smallholder farmers' owning 97% of the total maize land contribute 95% of the national maize production (CSA, 2011). On the other hand, commercial farms owning only 3% of the land contribute 5% of the total production. In Amhara region, maize production was done on 519,495.71 ha of land with the productivity of 3779 kg ha^{-1}, while in west Gojjam it was produced on 212,556.78 ha with the productivity of 4228 kg ha^{-1} (CSA, 2011).

The popularity of maize in Ethiopia is partly because of its high value as a food crop as well as the growing demand for the stover as animal fodder and source of fuel for rural families (Tsedeke et al., 2015). Maize is used in many ways than any other cereal. It is used as human food (accounting for 62% of all household cereal consumption), as a source of cash income (accounting for about 54%), as fuel (about 25%), feed for livestock and industrial purposes (Mosisa et al., 2002). Millions of people depend on maize for their daily food in sub-Saharan Africa. In Ethiopia, maize is a staple food and one of the main sources of calorie in the major maize-producing regions (Kebede et al., 1993). Farmers consume maize by preparing different dishes, including bread, *injera*, thick porridge, boiled maize, roasted maize and local beer. Green cobs are also sold in big cities and towns (Berhanu, Fernandez, Hassena, Mwangi, & Seid, 2007).

A number of factors are responsible for the low yield of the crop. Inappropriate crop nutrition management and poor soil fertility are the most important factors responsible for low yield of maize (Shah et al., 2009). In many parts of Africa including Ethiopia, repeated cultivation of land with inappropriate farming methods is causing severe depletion of nutrients and soil organic matter, posing a serious threat to agricultural productivity and sustainability (Endris & Dawid, 2015). Declining soil fertility is a serious limitation to crop production in Ethiopia. The primary causes are the loss of organic matter, macro and micronutrients' depletion, soil acidity, topsoil erosion and deterioration of physical soil properties (Zelleke, Agegnehu, Abera, & Rashid, 2010).

The basic concept underlying integrated nutrient management (INM) in crop production refers to combining of old and modern methods of nutrient management into ecologically sound and economically optimal farming system that uses the benefits from all possible sources of organic, inorganic and biological components in a judicious, efficient and integrated manner (Janssen, 1993). It aims to optimize the soil conditions by improving its physical, chemical and biological properties to enhance farm productivity and minimize land degradation (Esilaba et al., 2004). INM can not only increase crop productivity but also simultaneously and almost imperceptibly preserve soil resources. Its practices use farmyard manure, animal manures, green manures, crop residues, composts, industrial wastes, farm wastes, soil amendments, chemical fertilizers, cover crops, intercropping, crop rotations, fallows, conservation tillage (Janssen, 1993) and use of fertilizers fortified with micro-nutrients, use of bio-fertilizers (e.g. phosphate solubilizing bacteria, Azospirillum, Azotobacter, Rhizobium, and Potash mobilizing bio-fertilizers) (Herbert, 1998). Under INM practices, the losses through leaching, runoff, volatilization, emissions and immobilization are minimized, while high nutrient-use efficiency is achieved (Zhang et al., 2012).

Integrated nutrient management, means combining the use of mineral and organic nutrient sources offering better results than reliance on one source alone (Bekunda, 1999). Several studies have shown that grain yield and nutrient use efficiency was better under integrated nutrient management than from mere additive effects of sole applications (Amoah Alice, Masateru, Shuichi, & Kengo, 2012). Hence, the combined use of organic with inorganic fertilizers has considerable importance as to take remedial measures in fertility management and boosting crop production. Studies conducted by various researchers demonstrated the positive outcomes of integrated nutrient management in many areas (Laekemariam & Gidago, 2012). A balanced and integrated use of organic and inorganic nutrient sources may help sustain crop production (Gebrekidan, 2002). Therefore, the objective of this paper is to review the impacts of integrated nutrient application on phonological, vegetative growth and yield-related parameters of maize.

2. Effect of integrated nutrient application on phenological, vegetative growth and yield-related parameters

2.1. Phenological parameters days to 50% tasseling

Based on the finding of Kumar, Kumar, and Kumar (2018), days taken to tasseling were influenced significantly under fertility management practices. The higher days taken to tasseling were under application of 100% recommended fertilizer (RDF) (100 N + 60 P + 40 K + 20 Z kg ha^{-1}) with 25 t FYM ha^{-1} and the lower days to tasseling was observed from 50% RDF (50 N + 30 P + 20 K + 10 Z kg ha^{-1}) with 15 tons FYM ha^{-1}. Afe, Atanda, Aduloju, Ogundare, and Talabi (2015) also reported that plots treated with combined application of poultry manure (2.5 t ha^{-1}) mixed with 30 kg N ha^{-1} and foliar fertilizer commenced tasselling earlier at 38 days after planting while late (47 days) tasselling was recorded from the control. The above finding was in harmony with Bekele, Kibret, Bedadi, Balemi, and Yli-Halla (2018) who reported, the combined application of vermicompost, mineral P and lime significantly speeded up tasseling of maize. Early (102) days to tasseling were recorded with the application of lime, vermicompost, and mineral P fertilizer at the rate of 4 t ha^{-1}, 5 t ha^{-1}, and 40 kg ha^{-1}, respectively. The latest (112) days to 50% tasseling was obtained from the control. Amanullah Khalid (2015), reported that in case of applying poultry manure (5 t ha^{-1}) with phosphorus solubilizing bacteria (PSB), maximum (63) days to tasseling was recorded and lower (60) days was recorded with cattle manure (5 t ha^{-1}) with and without PSB.

2.1.1. Days to 50% silking
According to the study of Kumar et al. (2018), days to silking also influenced significantly under fertility management practices. The higher days taken to silking were under application of 100% RDF (100 N + 60 P + 40 K + 20 Z kg ha^{-1}) with 25 t FYM ha^{-1}. Based on Bekele et al. (2018) days to silking were also hastened with the application of 5 t vermicompost ha^{-1} and 20 kg P ha^{-1} with lime. Amanullah Khalid (2015) also reported that the application of cattle manures (5 t ha^{-1}) with phosphorus (160 kg P ha^{-1}) and with or without PSB showed that delayed (68 days) silking was recorded. Whereas early (66 days) silking was recorded with 160 kg P ha^{-1} without PSB.

2.1.2. Days to 90% physiological maturity
In accordance with Bekele et al. (2018), physiological maturity was significantly prolonged by applications of lime, vermicompost, and chemical P fertilizer. Application of the highest rates of all the three factors (lime = 4 t $CaCO_3$, VC = 5 t and P = 40 kg ha^{-1}) prolonged (75 days) maturity of maize by as much as 17 days compared to the control. This study was in harmony with the above finding since Amanullah Khalid (2015) reported that physiological maturity was significantly affected by animal manure with phosphorus solubilizing bacteria. Application of poultry manure (5 t ha^{-1}) with PSB indicated that delayed (104 days) physiological maturity was recorded and the early (101) days to physiological maturity were observed from the application of cattle manure (5 t ha^{-1}) with PSB. Days taken to maturity were found significantly higher under 100% recommended fertilizer (RDF) (100 N + 60 P + 40 K + 20 Z kg ha^{-1}) with 25 t FYM ha^{-1} method of fertility management (Kumar et al., 2018).

2.2. Vegetative growth parameters

2.2.1. Plant height
According to Priya, Kaushik, Sharma, and Priyanka (2014), plant height was significantly affected with complementary application of NPK and FYM, since plant height at harvest was maximum (237.25 cm) due to application of 100% NPK (120: 60:30 kg ha^{-1}) fertilizers with 10 t ha^{-1} FYM. Average maize plant height was significantly influenced by the application of organic and inorganic fertilizers. The highest (232 cm) plant height was recorded from application of composted domestic waste and stale cow dung at 10 t ha^{-1} with 70 kg N and 13 kg P2O5 ha^{-1}, while the lowest plant height was from unfertilized plot and sole composted domestic waste and stale cow dung at 5 t ha^{-1} 225 and 226 cm, respectively (Makinde & Ayoola, 2010). The above findings were similar with Ravi et al. (2012) who reported significantly higher (187.8 cm) plant height with an application of FYM at 10 t ha^{-1} with 100% RDF (150 N + 75 P_2O_5 + 37.5 K_2O kg ha^{-1}). Plant height was significantly influenced by even successive application of decomposed and dried FYM. Tallest (229 cm) plants were recorded when the successive application of 83/35 N/P_2O_5 kg ha^{-1} with 4 t FYM ha^{-1} in the year 2010 was applied, while shortest (222 cm) plants were obtained from the unfertilized plot (Zerihun, Sharma, Nigussie and Fred 2013).

2.2.2. Number of leaves per plant
The photosynthetic activity of a plant which influences growth and yield of the crop is also determined by the number of leaves on a plant. The rate of increase in the number of leaves

was observed to be maximum up to 45 days after sowing and thereafter decreased as the crop attained maturity. According to Adamu, Mrema Jerome, and Msaky (2015), application of full FYM, N and P at a rate of 10 t FYM, 150 kg N and 80 kg P ha^{-1} produced the highest average of nine leaves per plant, while the control had the lowest of six leaves per plant. At 60 days after sowing of baby corn, it was recorded that number of leaves produced with application of 5 t of FYM combined with 100 kg inorganic N was significantly higher, with an average of 11.14 leaves. On the other hand, the control plot produced significantly lower 7.29 leaves (Singh & Singh, 2016). In Singh and Singh (2016), Shilpashree, Chidanandappa, Jayaprakash, and Punitha (2012) have been also reported to observe similar results of significant effects on the number of leaves with the application of 100% recommended the dose of fertilizers applied along with the 7.5 t FYM. However, Sagar and Sharma (2015) reported that application of FYM and nitrogen did not significantly influence the number of leaves per plant.

2.3. Yield-related parameters

2.3.1. Number of cobs per plant

According to Shah et al. (2009), maximum (1.127) number of cobs per plant was observed where 260 kg ha^{-1} of the Urea with 1.5 t ha^{-1} of FYM was applied and it was followed by Urea alone (1.075), whereas minimum (1.020) number of cobs per plant was observed with FYM alone. Pant (2013) also reported that number of cobs per plant were significantly influenced by application of 10% K-sap (Kappaphycus) by 500 L of water ha^{-1} with RDF (120 N + 60 P + 40 K kg ha^{-1}) and the maximum number of cobs per plant was 1.33 while according to Ali et al. (2012), number of ears per plant was not significantly influenced by application of compost with nitrogen fertilizer. Wagh (2002), concluded that the number of cobs was significantly higher with the application of recommended NPK (225:50:50 kg ha^{-1}) with 5 t FYM ha^{-1} and *Azotobacter* with PSB.

2.3.2. Cob length

Cob length is an important yield contributing parameter of maize. It substantially contributes to grain yield of maize by influencing both numbers of grains cob^{-1} and grain size. Cob lengths of maize during 2009/2010 were significantly affected by fertilizer application. Maximum (16.85 cm) cob length during 2009 was from the application of 5 t compost with 75 kg ha^{-1} urea and 100 kg DAP ha^{-1} while the least (10.51 cm) was from 5 t compost ha^{-1}(Laekemariam & Gidago, 2012). From the report of El-Gawad and Morsy (2017), cob length was significantly affected in both study seasons, with an application of 10 t of compost with sheep manure and 50 Kg Urea ha^{-1}. Highest values of 19.42 and 18.83 cm cob length were recorded during the 2015 and 2016 seasons, respectively. According to Ashoka, Pujari, Hugar, and Desai (2008) also, application of RDF (150 N + 75 P_2O_5 + 40 K_2O kg ha^{-1}) along with micronutrient (25 $ZnSO_4$ + 10 $FeSO_4$ kg ha^{-1}) and Vermicompost (35 kg) gives significantly longer (7.40 cm) ear length than RDF (5.1 cm). Raman and Suganya (2018), also in harmony with the above studies and they conclude that application of 100% RDF (135 N + 62.5 P_2O_5 + 50 K_2O kg ha-^{1}) with Pressmud compost at rate of 5 t ha^{-1} resulted in the highest (22.68 cm) cob length, while the lowest (13.92) cob length was recorded from 100% RDF alone.

2.3.3. Number of rows per cob

Data regarding the number of rows per cob showed that except 2010 at *Chifisa*, it was significantly influenced by fertilizer application. During 2009, the highest (17 and 16.5) number of rows cob^{-1} were recorded at *Dendo Ofa* and *Chifisa* from the integration of compost (5 t ha^{-1}) with 75 and 50 kg ha^{-1} urea, respectively; whereas, during 2010, the highest (15.75) number of rows cob^{-1} at *Dendo Ofa* was recorded from the application of compost (5 t ha^{-1}) supplemented with 25 kg ha^{-1} urea. Meanwhile, statistically the lowest (15) value of rows cob^{-1} was recorded from sole compost and control (Laekemariam & Gidago, 2012). It was evident from the data that the number of grain rows cob^{-1} significantly influenced by different integrated nutrient management treatments. The maximum (13.87) number of grain rows cob^{-1} noticed under the application of 10% K-sap (Kappaphycus) by 500 L of water ha^{-1} with RDF (120 N + 60 P + 40 K kg ha^{-1}). The lowest

(12.13) numbers of grain rows cob-^{1} were recorded under the water spray with RDF (Pant, 2013). While according to Ali et al. (2012) data regarding the number of rows cob^{-1} had no significant response to the application of compost with nitrogen as well as the method of N application. Ahmad et al. (2017) also in agreement with Ali et al. (2012) and he reports that interaction effect of different manure forms and their levels, as well as nitrogen application timing, had non-significant to grain rows ear^{-1} of the maize.

2.3.4. Number of grains per row

Number of grains row^{-1} is an important parameter contributing to the economic yield. Based on the study of Laekemariam and Gidago (2012) during 2009, application of compost (5 t ha^{-1}) with 75 kg ha^{-1} urea at *Dendo Ofa* gave the maximum (33.58) number of grains row^{-1}. While at *Chifisa* maximum (33.25) number of grains row^{-1} was recorded from compost (5 t ha^{-1}) with 50 kg ha^{-1} urea. Data during 2010 also revealed that maximum (29 and 37) numbers of grains row^{-1} were obtained at *Dendo Ofa* and *Chifisa* from compost (5 t ha^{-1}) with 75 kg ha^{-1} urea fertilizer application, respectively. In El-Gawad and Morsy (2017) study also, number of grains row^{-1} was significantly increased due to the application of 10 t ha^{-1} of (compost and sheep manure) with 50 kg ha^{-1} Urea, which gave the maximum (33.97 and 34.29) number of grains row^{-1} in the 1st and 2nd seasons, respectively. The increase in the number of grains row^{-1} may be due to more photosynthetic activities and other nutrients from either organic or inorganic sources for plant development up to ear formation. While Ali et al. (2012) reported that data regarding the number of grains row^{-1} had no significant response to the application and interaction effect of compost and nitrogen as well as its application method. Ahmad et al. (2017) also in harmony with Ali et al. (2012) and he concluded that interaction effect of different forms of manure and their levels, as well as nitrogen application time, were found insignificant for grains row^{-1} of the maize.

2.3.5. Number of grains per cob

Admas, Gebrekidan, Bedadi, and Adgo (2015) reported that the interaction effects of N, compost and S fertilizers had significant effects on the grain number cob^{-1}. The highest (486) mean grain number cob^{-1} was counted in plots treated with high doses of N and compost together with medium S fertilizers (120 kg N, 10 t compost and 15 kg S ha^{-1}) whereas the lowest (153) was recorded in the control. This high increase in grain number cob^{-1} with the increase of N and compost along with medium S fertilizer rate might be due to the synergistic effects of fertilizers that improved nutrient use efficiencies and normal development of maize. Application of recommended dose of NPK (150:75:40 kg ha^{-1}) with FYM at 10 t ha^{-1} recorded significantly higher (458.5) number of grains cob^{-1}, while the lower (290.8) number of grains cob^{-1} were noticed in the treatment receiving 100% recommended dose of NPK through chemical fertilizer (150:75:40 kg ha^{-1}) (Mahesh et al., 2010). Based on the trial of Tukur and Amit (2017) the grains number cob^{-1} was significantly influenced by the application of integrated nutrient management. Thus, the higher (423) number of grains cob^{-1} was noticed from the application of 50% RDF (60 N + 30 P + 20 K kg ha^{1}) with each of 5 t ha^{-1} of the FYM and poultry manure, whereas 100% RDF (120 N + 60 P + 40 K kg ha^{-1}) produced least (341) grains number cob^{-1}. Numbers of grains cob^{-1} were peaked at the combination of either 80 or 120 kg N ha^{-1} with 15 t ha^{-1}of poultry manure (Uwah, Afonne, & Essien, 2011).

2.3.6. Grain yield kg per hectare

According to Endris and Dawid (2015) mean grain yield of maize was significantly affected by soil fertility management both in the year 2010 and 2011. The first year's data indicated that the highest grain yield at *Burka* was in response to the full dose of recommended mineral NP (200 kg Urea and DAP ha^{-1}) fertilizers followed by integrated soil fertility management, 50% recommended NP (100 kg Urea and DAP ha^{-1}) with 50% compost (2 t ha^{-1}) resulting grain yield of 4772.8 and 4643.7 kg ha^{-1} year^{-1}, respectively. The data recorded in the second year was also similar to that of the previous year. Hence, there was a significant maize yield difference in response to the treatments tested across the different locations of the trial. At *Burka*, the highest grain yield was obtained from the application of 100% recommended NP followed by 50%

recommended NP with *Tithonia* biomass and 50% recommended NP with 50% compost (2 t ha^{-1}) corresponding to 4852, 4725 and 4010 kg ha^{-1} year^{-1}, respectively. The highest records of grain yield at first year in *Wenji* and *Waktola* were 4684.3 and 3936.8 kg ha^{-1} year^{-1} from the application of 50% recommended NP with 50% *Tithonia* biomass and 50% recommended NP with 50% compost respectively. Based on the finding of Pandey and Awasthi (2014) application of FYM in conjugation with chemical fertilizers resulted in higher grain yield over the RDF. The highest (2929 kg ha^{-1}) grain yield of maize was recorded at the application of RDF (120 N + 60 P_2O_5 + 40 K_2O kg ha^{-1}) with FYM (10 t ha^{-1}), while the lowest (982 kg ha^{-1}) grain yield was from control. The average grain yield was significantly higher (5.8 and 4.9 t ha^{-1}) in plots which receive integrated plant nutrient (15 t ha^{-1} FYM with 60:30:30 NPK kg ha^{-1}) respectively, in the plots with Improved and Local varieties compared to the plots with farmers' level of management (4.3 and 3.5 t ha^{-1}). Moreover, maize yield was increased 25–30% by adopting only integrated plant nutrient application over farmers' practices for both varieties. The combination of integrated plant nutrient application and improved cultivar produced 64% more yield (5.8 t ha^{-1}) compared to the farmers' practice and Local cultivar (3.5 t ha^{-1}) (Tejendra & Gurung Gam, 2010). While Abera, Feyissa, and Yusuf (2005) reported that the mean grain yield of maize was non-significantly affected by the interaction effect of N with P, N with FYM and P with FYM in intercropping system. Whereas three-way interaction of N, P and FYM compared to sole and intercropped with recommended rate significantly affected mean grain yield of maize. Sole planted maize with recommended NP (110 N, 20 P kg ha^{-1} and FYM (16 t ha^{-1}) gave higher yield. Higher (6116, 6102 and 5950 kg ha^{-1}) mean grain yield was obtained from intercropping and combinations of 69/10/4, 69/20/4 and 46/10/8 N- P-FYM kg-t ha^{-1} respectively.

2.3.7. Thousand-grain weight

Among various parameters contributing to the economic yield of maize, 1000 grains weight is of prime importance. It directly relates to the yield of the crop. The data reveal that maximum (327.54 g) 1000 grains weight was recorded in the application of 260 kg ha^{-1} of Urea with 15 t ha^{-1} of FYM. On the contrary, the minimum (284.39 g) 1000 grains weight was noted with the sole application of FYM (15 t ha^{-1}) (Shah et al., 2009). According to (Rizwan et al., 2006) data analysis indicated that 1000 grains weight was influenced by sheep manure and nitrogen levels. Thousand grains weight increased significantly in all three levels of sheep manure (3, 4 and 5 t ha^{-1}) with incremental of N levels from 0 to 120 kg ha^{-1}. Integrated application of sheep manure and urea produced heaviest (214 g) grains than the sole application of nitrogen. Admas et al. (2015) also in agreement with the above finding and they conclude that combined application of N, compost and S fertilizers affect 1000 seed weight significantly. The highest (492 g) means 1000 seed weight was recorded in plots treated with 120 N, 15 S kg and 10 t compost ha^{-1}, while the lowest (240 g) was in the control. Such a high increase in 1000 seed weight might be also due to the synergistic effects of combined fertilizers for better growth and grain filling of maize. The data on test weight revealed that the various treatments exerted a significant impact upon test weight. Amongst the integrated nutrient management, application of 75% RDF (75 N + 45 P_2O_5 + 30 K_2O kg ha^{-1}) with 50% N through FYM (5 t FYM ha^{-1}) result the maximum (28.67 g) test weight. On the other hand, the lowest (22.73 g) test weight was recorded from application of only 50% RDF (50 N + 30 P_2O_5 + 20 kg K_2O kg ha^{-1}) (Maravi, 2006).

2.3.8. Biomass yield kg per hectare

According to Dilshad et al. (2010) biological yield represents a total amount of above ground biomass accumulated by the plant. In Dilshad et al. trial, during two consecutive years (2005 and 2006), application of 50% NPK (60-45-30 kg ha^{-1}) with 50% FYM (10 t ha^{-1}) produced the highest biological yield of 8579 and 8475 kg ha^{-1} respectively. Shah, Shah, Tariq, and Afzal (2007) also reported that the results showed that all fertilizer treatments significantly increased the biological yield of maize compared with the control treatment. The maximum biological yield of 12,410 kg ha^{-1} was obtained in treatment receiving N from urea and compost in 75:25 ratio to supply total N of 120 kg ha^{-1}. Under application of 100% NPK (120 N, 60 P_2O_5 and 40 K_2O kg ha^{-1}) and 5 t FYM with Azotobacter and PSB (as seed treatment at 20 g kg^{-1}) the maximum biological yield was 12,830 and 12,720 kg ha^{-1} in two consecutive years of 2010 and 2011 respectively, while the lowest (5810 and 5790 kg) biological yield was recorded from unfertilized plot in 2010 and 2011 respectively (Tomar et al., 2017).

2.3.9. Stover yield kg per hectare

Among the integrated nutrient management practices, 100% RDF (135 N + 62.5 P_2O_5 + 50 K_2O kg ha^{-1}) with pressmud compost at the rate of 5 t ha^{-1} significantly affect the Stover yield and the highest was (9031.08 kg ha^{-1}). 100% RDF alone recorded the least (6781.41 kg ha^{-1}) Stover yield (Ashoka et al. (2008). Based on the finding of Tukur and Amit (2017) application of 5 t ha^{-1} of the poultry manure with 50% RDF (50 N + 30 P + 20 K + 10 Z kg ha^{-1}) produce highest (13.843 t ha^{-1}) stover yield whereas, application of 100% RDF (100 N + 60 P + 40 K + 20 Z kg ha^{-1}) produced lowest (8.321 t ha^{-1}) stover yield. The stover yield of maize was also significantly greater in treatment receiving N from urea and compost in 75:25 ratio to supply total N of 120 kg ha^{-1}. These results indicated that under the given experimental conditions, the combined application of compost and urea significantly improved stover yield of maize only when the N contribution from urea was 50% or greater. Compost alone did not prove as effective as urea alone (Shah et al., 2007). Maximum stover yield was recorded under application of 100% NPK (120 N: 60 P_2O_5:40 K_2O kg ha^{-1}) and 5 t FYM with Azotobacter and PSB (as seed treatment at 20 g kg^{-1}) which was 7560 and 7360 kg ha^{-1} of stover yield for two consecutive years 2010 and 2011 respectively, While the lowest (4450 and 4370 kg) stover yield was recorded from unfertilized plot in 2010 and 2011 respectively (Tomar et al., 2017).

3. Conclusion

Maize production in Ethiopia has been facing critical constraints due to the gradual decline of soil fertility. To alleviate this problem in the country, a number of fertilizer research attempts have been conducted on maize at different research institutions but the outputs of various researches in the country confirmed variable results because of differences in soil types, agro-ecology, varieties used and crop management. As a result, the farmers were applying different rates although the growing costs of inorganic fertilizers did not encourage the poor farmers to use the full recommended dose. Thus, to offer low input technology on soil fertilization, research efforts have been made on the integrated application of different sources of organic and inorganic fertilizers.

Accordingly, an experiment conducted in *Bako* concluded that use of 12 t ha^{-1} of FYM with 28/12 NP_2O_5 kg ha^{-1} saved up to 75% cost of commercial fertilizer. A trial at *Wolaita* indicated that combined use of compost (5 t ha^{-1}) with inorganic (50 kg urea and 100 kg DAP ha^{-1}) was suggested to obtain the better yield of maize and improving soil on a sustainable basis. Another field experiment done in Western *Oromiya*, application of 150/50 kg ha^{-1} of Urea and DAP with 4 t FYM ha^{-1} was recommended for sustainable production of maize. An experiment conducted at *Wujiraba* Watershed indicates increasing yield and yield components, nutrient concentrations of maize with the application of 120 kg N and 15 kg S ha^{-1} with 10 t $ha^{-1}$of compost. Another trial proceeded at acidic nitosol of Southwestern Ethiopia concluded that application of 50% recommended NP and 50% compost gave the highest grain yield. A field experiment done at *Wolaita* also indicates applying compost at rate of 5 t ha^{-1} fortifying with urea was better. Another work done at *Ebantu* district, showed that combination of vermicompost at (2.5 t ha^{-1}) and mineral P (20 kg ha^{-1}) with lime (4 t ha^{-1}) was recommended for reclaiming soil acidity and improve nutrients for maize.

Therefore, integrated use of mineral fertilizers with vermicompost, FYM and compost should be promoted in potential maize agro-ecologies and application of them must be included in maize production packages and soon taken up through government extension services to enhance soil fertility and produce maize at low cost, while giving human food and animal feed in maize based farming system in Ethiopia.

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