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Effect of Combined Application of NPS Fertilizer and Compost on Phenology and Growth of Quality Protein Maize (Zea Mays L.) at Jimma, South Western Ethiopia

Sisay Gurmu[1*]***, Adugnaw Mintesnot***[2]

[1]*Department of Agronomy, Jimma Agricultural Research Center, Ethiopia*
[2]*Department of Agronomy, Jimma University College of Agriculture and Veterinary Medicine, Ethiopia*

****Corresponding Author:** Sisay Gurmu, Department of Agronomy, Jimma Agricultural Research Center, Ethiopia. Email Id: sis.sis1835@gmail.com.*

ABSTRACT

Field experiment had been conducted in Jimma Zone during the 2017 main cropping season with the objective to determine the phonological and vegetative performance of quality protein maize to combined application of NPS fertilizer and compost on Nitisols of Jimma, Southwestern Ethiopia. Five rates of NPS fertilizer (0/0/0, 23/17.25/3.2, 46/34.5/6.4, 69/51.75/9.6, 92/69/12.8 kg ha^{-1} $N/P_2O_5/S$) and 5 rates of compost based on N-equivalence of recommended fertilizer rate (0, 2.3, 4.6, 6.9 and 9.2 ton ha^{-1}) laid down in RCBD with factorial arrangement in three replications. Accordingly, all of the phonological and growth parameters were significantly affected by combined application of NPS fertilizer and compost rates, where non-fertilized plants were inferior in all parameters. The collected data's were subjected to ANOVA using SAS software version 9.3. The results revealed that combined application of NPS fertilizer and compost significantly (P<0.05) affected days to 50% tasseling, number of leaves per plant, stem girth(stem diameter), days to 90% maturity, and highly significantly (P<0.01)affected days to 50% silking, leaf area index and plant height. The compost application rates alone and control significantly delayed days to 50% tasseling, days to 50% silking and days to 90% maturity. Significantly the highest plant height (242.77cm) and leaf area index (3.61) were recorded from combined application of full NPS fertilizer with 9.2 ton ha^{-1} compost. Whereas, the thickest stem diameter (2.49 cm) was recorded from combined application of 69/51.75/9.6 kg ha^{-1} $N/P_20_5/S$ with 9.2 ton ha^{-1} compost. The highest number of leaves per plant was obtained from combined application of 92/69/12.8 kg ha^{-1} $N/P_20_5/S$ with 4.6 ton ha^{-1} compost. It was concluded that combined application of 69/51.75/9.6 kg ha^{-1} $N/P_20_5/S$ with 6.9 ton ha^{-1} compost can be used for promoting vigorous maize growth and development.

Keywords: *Maize, Phenology, Growth, Fertilizer and compost*

INTRODUCTION

Globally, maize (Zea mays L.) is among the leading cereals in production along with rice and wheat. In Africa, Ethiopia is the third largest maize producer next to Nigeria and Egypt (FAOSTAT, 2016). Maize ranks second after teff in area coverage and first in total production in Ethiopia (CSA, 2017). In 2016/17 the maize crop area and grain production in Ethiopia was 2,135,572 ha and 7, 8471,175 ton respectively with productivity of 3675 kg ha^{-1} (CSA, 2017). It is a good source of carbohydrates, fat, protein and some important vitamins (B6, A and E) and minerals (magnesium, potassium and phosphorus), but deficient in essential amino acids viz., lysine and tryptophan that reduces its biological value (Mbuya et al., 2011). The amount of these deficient amino acids has been increased by incorporating opaque-2 gene in quality protein maize (QPM) (Bisht et al., 2012). It produces 70-100% more of lysine and tryptophan than the most modern varieties of tropical maize (Vivek et al., 2008).

Declining soil fertility and management of plant nutrients aggravate the challenge of agriculture to meet the world increasing demand for food in a sustainable way. Insufficient application of nutrients and poor soil management, along with harsh climatic conditions and other factors, have contributed to the degradation of soils including soil fertility depletion in developing countries, especially in SSA (Goulding et al., 2008). Poor soil fertility is one of the principal factors that limit maize productivity in maize growing areas of Ethiopia (Abebayehu et al., 2011).

Among plant nutrients nitrogen is a vitally important, a major yield determining nutrient and its availability in sufficient quantity throughout the growing season is essential for optimum maize growth (Kogbe and Adediran, 2003). It is a component of protein, nucleic acids and other compounds essential for plant growth process (Onasanya et al., 2009). Whereas phosphorus is the second most important nutrient element (after nitrogen) limiting agricultural production (Kogbe and Adediran, 2003). It is used for growth, utilization of sugar and starch, photosynthesis, metabolic process which leads to higher yield of the crop (Ayub et al., 2002).

In Ethiopia, initial results of demonstration of blended fertilizers that include N, P, K, S, Zn, B conducted across 25,000 smallholder farms indicate that yield increases between 15-85% can be achieved and DAP is being gradually substituted by NPS starting from 2013/14 to meet the sulfur demand of most Ethiopian soils (EthioSIS, 2013). Sulfur deficiencies are occurring with greater frequency in more locations throughout Ethiopia. It is used in plants for the synthesis of the amino acids, cysteine and methionnine, various enzymes and coenzymes, and it is an integral component of membranes, lipids and chlorophyll proteins (Scherer, 2001).

Compost is one of the organic fertilizers and it is an alternative source of plant nutrients (Vanlauwe et al., 2012; Ngwira et al., 2013). Application of compost improves soil fertility parameters, such as alleviates acidification, benefits better microbial activity, soil aeration, increase soil organic matter, increases CEC, P availability and sustainable increase in crop yields (Diacono and Montemurro, 2010). Use of compost and sometimes in combination with inorganic fertilizers gave maximum grain yields of QPM (Balai et al. 2011).

To ensure soil productivity, plants must have an adequate and balanced supply of nutrients that can be realized through integrated nutrient management where both natural and man-made sources of plant nutrients are used (Gruhn et al., 2000). Various long-term research results have shown that neither organic nor mineral fertilizers alone can achieve sustainability in crop production (Tadesse et al., 2013). Rather, integrated use of organic and mineral fertilizers has become more effect in maintaining higher productivity and stability through correction of deficiencies of primary and secondary macronutrients and micronutrients (Aulakh et al., 2010).

Currently, the lack of balanced and integrated application of nutrients reduced the yield potential of QPM and other maize varieties in most maize producing areas of Ethiopia. The productivity of maize is low as a result of continuous cropping, inadequate use of fertilizer inputs, very low or lack of the use of organic manure neither alone nor in combinations with mineral fertilizers. Since, the use of inorganic fertilizer in maize production is costly and its effect is short term, there is another option to use organic fertilizer in integrated form.

Hence, for better dissemination and adoption of QPM hybrid there is a need to understand its performance with various agronomic management practices, of which nutrient management is vital in influencing the phonological and growth performance of the crop. Therefore, this study was initiated with the objective to determine the phonological and vegetative performance of quality protein maize to combined application of NPS fertilizer and compost.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Jimma zone of Oromia Regional State during the 2017 main cropping season from June to November. Jimma zone is one of the most important maize producing areas of the region. The experimental site is located at $7^{0}66'$ 28" N latitude and $36^{0}79'$ 45" E longitudes and at an altitude of 1728 meters above sea level. The long-term (ten years) mean annual rainfall of the study area was 1714.0 mm with a maximum and minimum temperature of 26.32^{0}c and 12.34^{0}c respectively (JARC, 2017). The metrological data during cropping season was presented in figure 1 below.

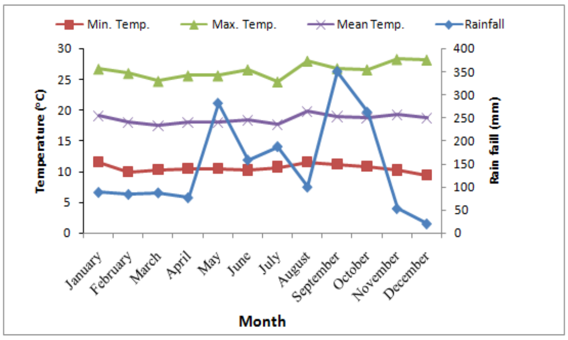

Figure1. *Meteorological data during crop growth period at Jimma in 2017*

To have insight on some of the physico-chemical properties of the experimental soil, samples were taken randomly from the representative composite soil samples in a zigzag method from various gradients using auger (0-20 cm depth) from the entire field and analyzed. The experimental soil was sandy clay loam in its textural classification (FAO, 1990) with the pH value of 5.03 which was strongly acidic (Batjes, 1995) and ideal for the production of most field crops.

The total nitrogen of the sample soil determined by wet digestion procedure of Kjeldahl method (Bremner, 1996) was about 0.13%, which was medium for crop growth and development according to Berhanu, (1980). The soil available phosphorous was 4.42 mg kg^{-1} which extracted by Bray II method and determined using spectrophotometer following the procedure described by Murphy (1968). According to Tekaligh and Haque (1991) the experimental soil has low level of available phosphorous. Marschner (1995) stated in most cases, soils with pH values less than 5.5 are deficient in P. The organic carbon (OC) content of the soil was determined by wet digestion procedure as described by Walkley and Black method (Jackson, 1973). Accordingly, the sample soil has medium OC content (3.18%) according to Tekalign (1991). The soil cation exchange capacity (CEC) of the sample soil was 15.71 (cmol(+)kg^{-1}) which was determined by 95% ethanol extraction method and it is medium for crop growth and development according to Landon (1991). The soil bulk density (BD) of the experimental site was 1.20 (g cm^{-3}) which is ideal for crop root penetration and aeration in sandy clay loam soils (Tekalign, 1991). Hunt and Gilkes (1992) found for optimum movement of air and water through the soil, it is desirable to have soil with a low BD (<1.5 g cm^{-3}). Details of soil properties are given in table 1.

The pH of compost (8.43) which was moderately alkaline according to Batjes (1995) d it is capable of ameliorating the acidic content of the soil (Onwudiwe et al., 2014). Most finished composts will have pH values in the range of 5.5 to 8.5 (Canadian Compost Guidelines, 1996). The total N of the sample compost determined by wet digestion procedure of Kjeldahl method (Bremner, 1996) was about 1.00%, while OC contents of the compost were 6.88%, with a resultant narrow C:N ratio of 6.88. It indicates the prepared compost was well decomposed to the level of average soil organic matter. The C:N ratio of compost should drop below 20% before application to the soil (Brady and Weil, 2002) to have expected impact from application of the compost. Details of compost properties are given in table 2

Table1. *Soil physico-chemical properties of the experimental site*

Soil characters	Measured value
pH	5.03
Organic carbon (%)	3.18
Total N (%)	0.13
Available P (mg kg^{-1})	4.42
CEC(cmol(+) kg^{-1} of soil)	15.71
C:N ratio	24.46
Bulk density (g cm^{-3})	1.20
Soil texture	
Sand (%)	69
Clay (%)	26
Silt (%)	5
Texture Class	Sandy clay loam

Table2. *Chemical characteristics of compost used in the experiment*

Compost characters	Measured value
pH	8.43
Organic carbon (%)	6.88
Total N (%)	1.00
Available P (%)	1.11
CEC(cmol(+) kg^{-1} of soil)	24.40
C:N ratio	6.88

Experimental Design and Treatments

The experiment had conducted with 5 rates of NPS fertilizer (0/0/0, 23/17.25/3.2, 46/34.5/6.4, 69/51.75/9.6, 92/69/12.8 kg ha^{-1} N/P_2O_5/S) and 5 rates of compost based on N-equivalence of recommended fertilizer rate (0, 2.3, 4.6, 6.9 and 9.2 ton ha^{-1}) the details in table 3. The blended NPS fertilizer (19N–38P_2O_5-0K-7S grade) rates was set based on N and P_2O_5 recommendation for maize on Nitisols of Jimma area (92 kg ha^{-1} N and 69 kg ha^{-1} P_2O_5) (Wakene *et al*., 2011). The remaining nitrogen calculated and applied as urea at 30 days after emergence for each treatment. The treatments were arranged in Randomized Complete Block Design (RCBD) in 5 x 5 factorial arrangements with three replications. The total treatment was 25 and there were 75 total observations in this experiment (Table 4). The net plot size of 4.5m width x 3.6 m length (16.2 m^2) and the total experimental area 33m x 58.8 m (1940.4m^2) was used. The N fertilizer equivalence value of applied compost at the rates of 2.3, 4.6, 6.9 and 9.2 ton ha^{-1} were 23, 46, 69 and 92 kg N ha^{-1} respectively. The compost rates were calculated on dry weight basis and applied to the respective experimental plots. It incorporated into the soil and thoroughly mixed in the upper 15 to 20 cm soil depth at time of planting using human power.

Table3. *NPS fertilizer and compost treatment application*

NPS rate %	Elemental $N/P_2O_5/S$ kg ha^{-1}	Commercial product NPS kg ha^{-1}	1st round N kg ha^{-1} in blended NPS	Urea kg ha^{-1} at 30DAE	Blended NPS gm $plant^{-1}$ at planting	2nd round Urea gm $plant^{-1}$ at 30 DAE	% Compost rate	Compost ton ha^{-1} (DB)	Compost kg $plot^{-1}$ (DB)
0	0/0/0	0.0	0.0	0.0	0.00	0.00	0	0.0	0.00
25	23/17.25/3.2	45.5	18.8	31.2	1.02	0.70	25	2.3	3.73
50	46/34.5/6.4	91	37.6	62.4	2.05	1.40	50	4.6	7.45
75	69/51.75/9.6	136.5	56.4	93.6	3.07	2.11	75	6.9	11.18
100	92/69/12.8	182	75.2	124.8	4.10	2.81	100	9.2	14.90

Note: *DAE= Days after emergency; DB=Dry base; Compost applied based N equivalence at recommended rate (92 kg ha^{-1} N) at which 100gm dry compost gave 1gm N based on laboratory analysis*

Medium maturing maize variety BHQPY545 was used for the study. It was released by Bako Agricultural Research Centre through the National Maize Research Program in 2008. It performs well in agro-ecology of 1000-2000 m.a.s.l with rainfall of 1000-1200 mm. It can give 8.0-9.5 and 5.5-6.5 t ha^{-1} grain yields under on-station and on-farm experiments, respectively. It was moderately tolerant to rust, blight and gray leaf spot with maturity date of 138 and 25 kg ha^{-1} seed rate.

Table4. *Details of treatment combination*

No.	NPS (%) x Compost (%)	Treatment description
1	Control	Control
2	0%x25%	2.3 t ha^{-1} Compost
3	0%x50%	4.6 t ha^{-1} Compost
4	0%x75%	6.9 t ha^{-1} Compost
5	0%x100%	9.2 t ha^{-1} Compost
6	25%x0%	23/17.25/3.2 kg ha^{-1} $N/P_2O_5/S$
7	25%x25%	23/17.25/3.2 kg ha^{-1} $N/P_2O_5/S$ +2.3 t ha^{-1} Compost
8	25%x50%	23/17.25/3.2 kg ha^{-1} $N/P_2O_5/S$ +4.6 t ha^{-1} Compost
9	25%x75%	23/17.25/3.2 kg ha^{-1} $N/P_2O_5/S$ +6.9 t ha^{-1} Compost
10	25%x100%	23/17.25/3.2 kg ha^{-1} $N/P_2O_5/S$ +9.2 t ha^{-1} Compost
11	50%x0%	46/34.5/6.4 kg ha^{-1} $N/P_2O_5/S$
12	50%x25%	46/34.5/6.4 kg ha^{-1} $N/P_2O_5/S$ +2.3 t ha^{-1} Compost
13	50%x50%	46/34.5/6.4 kg ha^{-1} $N/P_2O_5/S$ +4.6 t ha^{-1} Compost
14	50%x75%	46/34.5/6.4 kg ha^{-1} $N/P_2O_5/S$ +6.9 t ha^{-1} Compost
15	50%x100%	46/34.5/6.4 kg ha^{-1} $N/P_2O_5/S$ +9.2 t ha^{-1} Compost
16	75%x0%	69/51.75/9.6 kg ha^{-1} $N/P_2O_5/S$
17	75%x25%	69/51.75/9.6 kg ha^{-1} $N/P_2O_5/S$ +2.3 t ha^{-1} Compost
18	75%x50%	69/51.75/9.6 kg ha^{-1} $N/P_2O_5/S$ +4.6 t ha^{-1} Compost
19	75%x75%	69/51.75/9.6 kg ha^{-1} $N/P_2O_5/S$ +6.9 t ha^{-1} Compost
20	75%x100%	69/51.75/9.6 kg ha^{-1} $N/P_2O_5/S$ +9.2 t ha^{-1} Compost
21	100%x0%	92/69/12.8 kg ha^{-1} $N/P_2O_5/S$
22	100%x25%	92/69/12.8 kg ha^{-1} $N/P_2O_5/S$ +2.3 t ha^{-1} Compost
23	100%x50%	92/69/12.8 kg ha^{-1} $N/P_2O_5/S$ +4.6 t ha^{-1} Compost
24	100%x75%	92/69/12.8 kg ha^{-1} $N/P_2O_5/S$ +6.9 t ha^{-1} Compost
25	100%x100%	92/69/12.8 kg ha^{-1} $N/P_2O_5/S$ +9.2 t ha^{-1} Compost

Experimental Procedures and Crop Management

The field was prepared by plowing three times. Maize was hand planted on the 29th of May 2017 on a plot size of 3.60mx4.50m =16.2m^2. Two seeds were placed per hill to ensure the desired stand in each treatment and thinned to one plant with plant population of 44,444 plants ha^{-1}. Thinning was done at 3-4 leaves stage. The outermost rows at both sides of plots were considered as borders. The path between plot and block was 1 m and 1.5 m, respectively and the planting space was 75cm x 30cm between rows and plant, respectively. In accordance with specifications of the design, each treatment was assigned randomly to experimental units within a block. All data were determined in the center rows of each plot.

Blended NPS fertilizer was applied at spot for each plant at the time of planting. The remaining nitrogen calculated and applied in split at 30 days after emergence for each treatment. The N content of compost was determined before application to determine the application rate of compost for each treatment, which was based on recommended N equivalent rate for the test crop. The moisture content was calculated from the fresh compost after oven dried at 105°C until constant weight attained to determine the different rates of compost applied for each treatment on dry weight basis.

Harvesting and threshing were done by hand. The fall army warm (FAW) pest was controlled through both manual collections of the insects and by chemical application (Diazinone 1 liter ha^{-1}) during cropping season. The chemical was applied 2 times before the crop starts tasseling at two weeks interval. Then after, all the remaining necessary agronomic practices and crop management activities were undertaken.

Data Collection and Analysis

Data collected were related to growth and yield parameters. These data were collected from the net plot of each treatment to avoid the border effects. The growth and vegetative parameters considered in the current study were days to 50% tasseling, days to 50% silking, days to 90% physiological maturity, leaf area index, number of leaves per plant, stem diameter and plant height from six randomly selected plants.

Days to 50% tasseling and silking were collected by counting the number of days from planting time to 50% tassel and silk production in each plot. Days to 90% physiological maturity was collected by counting the number of days from planting time to when 90% of plants formed black layer at the base of the kernel.

Leaf area index was calculated as the ratio of total leaf area per area of land (cm^2) occupied by the plant (Sestak et al., 1971). The number of leaves per plant was counted at 50% tasseling stage. Stem diameter was measured at 50cm from the ground level using caliper. Plant height was measured at ground level to terminal stem using measuring stick at the point where the tassel starts branching.

Finally, collected data were subjected to the analysis of variance (ANOVA) by using Statistical Analysis System (SAS) version 9.3 and mean separations were carried out using Least Significance Difference (LSD) at 5 or 1% significance level.

Results and Discussions

Days To 50 % Tasseling and Silking

The number of days required for 50% tasseling was significantly ($P < 0.05$) affected by the interaction of NPS fertilizer and compost, while highly significantly ($p < 0.01$) affected by both main effect of NPS fertilizer and compost (Table 9). Days to 50% tasseling delayed at control and 2.3 ton ha^{-1} compost but further increasing compost application rate to 9.2 ton ha^{-1} reduced days to 50% tasseling. The longest days to 50% tasseling (90.00) was recorded from control followed by 2.3 ton ha^{-1} compost. Whereas, the shortest days to 50% tasseling (81.33) was recorded from combined application of full rate of NPS fertilizer (100%) with 9.2 ton ha^{-1} and 6.9 ton ha^{-1} compost; 69/51.75/9.6 kg ha^{-1} N/$P_2 0_5$/S (75%) with 9.2 ton ha^{-1} and 6.9 ton ha^{-1} compost (Table 5). Days to 50% tasseling was delayed by 8.67 days (10.7%) at control compared to treatments those take 81.33 days to 50% tasseling.

The interaction of NPS fertilizer and compost, and the main effect of NPS fertilizer and compost were highly significantly ($P < 0.01$) affected days to 50% silking (Table 5). Days to 50% silking delayed at control and 2.3 ton ha^{-1} compost but further increasing compost application rate to 9.2 ton ha^{-1} reduced days to 50% silking. The longest days to 50% silking (94.00) was recorded from the control followed by 2.3 ton ha^{-1} compost. The shortest days to 50% silking (83.33) was recorded from combined application of full rate of NPS fertilizer (100%) with 9.2 ton ha^{-1} compost; 69/51.75/9.6 kg ha^{-1} N/$P_2 0_5$/S (75%) with 9.2 ton ha^{-1} and 6.9 ton ha^{-1} compost (Table 5). Days to 50% silking were delayed by 10.67 days (12.81%) at control compared to treatments that takes 83.33 days to 50% silking.

Table5. *Interaction effects of NPS fertilizer and compost on days to 50% tasseling and silking at Jimma in 2017*

N/P_2O_5/S (Kg ha^{-1})	Tasseling day					Silking day				
	Compost (ton ha^{-1})									
	0	2.3	4.6	6.9	9.2	0	2.3	4.6	6.9	9.2
0/0/0	90.00^{a}	88.00^{ab}	86.67^{b}	86.00^{bc}	84.33^{cd}	94.00^{a}	91.67^{ab}	90.00^{bc}	88.67^{cd}	87.00^{d}
23/17.25/3.2	82.00^{e}	82.00^{e}	82.00^{e}	81.67^{e}	81.67^{e}	84.33^{e}	84.00^{e}	84.00^{e}	84.00^{e}	84.00^{e}
46/34.5/6.4	82.33^{de}	82.00^{e}	81.67^{e}	81.67^{e}	81.67^{e}	84.00^{e}	83.67^{e}	83.67^{e}	84.00^{e}	83.67^{e}

69/51.75/9.6	82.00^{e}	81.67^{e}	81.67^{e}	81.33^{e}	81.33^{e}	84.00^{e}	83.67^{e}	83.67^{e}	83.33^{e}	83.33^{e}
92/69/12.8	82.00^{e}	82.00^{e}	81.67^{e}	81.33^{e}	81.33^{e}	84.00^{e}	83.67^{e}	83.67^{e}	83.67^{e}	83.33^{e}
Mean	82.80					85.08				
LSD(0.05)	2.074					2.358				
CV (%)	1.19					1.38				
F-test	*					**				

Note: *LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.*

The application of N, P and S nutrients in blended NPS fertilizer and N also from urea combined with compost leads the crop to vigorous and enhanced vegetative growth and ultimately the crop tassel and silk early instead of prolonged vegetative growth. The nutrients in the compost gradually mineralized and become available for the crop. Despite that, the application of compost delays days to tasseling and silking compared to combined application of NPS fertilizer and compost and NPS fertilizer without the use of the compost. Sufficient nutrient application results in rapid growth and hastened tasseling, while too little or no nutrient application, resulted in slow growth and delayed tasseling and silking (Cock and Ellis, 1992). These results are in line with those of Ayoola and Makinde, (2009) and Uwah et al., (2011) who observed a reduction in number of days to 50% tasseling and silking in maize with increased rates of fertilizers.

Days to 90% Maturity

The number of days required for 90% maturity was significantly ($P < 0.05$) influenced by the interaction of NPS fertilizer and compost, and highly significantly ($P < 0.01$) affected by both main effect of NPS fertilizer and compost (Table 9). The combined application of 92/69/12.8 kg ha^{-1} N/P$_2$0$_5$/S (100%) with 9.2 ton ha^{-1} (100%) and 6.9 ton ha^{-1} (75%) compost took minimum days to physiological maturity (142.33 days). Whereas, the maximum (153.00 days) was recorded from control treatment which was not statistically significant from 2.3 ton ha^{-1} (25%) and 4.6 ton ha^{-1} (50%) compost (Table 6). The combined application of 92/69/12.8 kg ha^{-1} N/P$_2$0$_5$/S (100%) with 9.2 and 6.9 ton ha^{-1} compost hastened days to maturity by 6.97% (10.67 days) as compared to control.

Application of NPS fertilizer and compost at higher rates gave early maturity because of vigorous growth, early tasseling and silking of the crop, while plants at the lower nutrient application matured lately because of insufficient nutrients. This result is in line with the report by Dagne (2016) who reports early maturity days were recorded with the application of blended fertilizer whereas the longest days to maturity were recorded for control.

Plant Height

Plant height was highly significantly ($P < 0.01$) affected by the interaction of NPS fertilizer and compost, and also by the main effect of NPS fertilizer and compost (Table 9). Numerically, the longest plant height (242.77cm) was recorded from combined application of 92/69/12.8 kg ha^{-1} N/P$_2$0$_5$/S (100%) and 9.2 ton ha^{-1} (100%) compost. While, the shortest plant height (158.17cm) was recorded from the control which was not statistically significant from 2.3 ton ha^{-1} (25%) compost (Table 6). The plant height was increased by 53.49% at combined application of 92/69/12.8 kg ha^{-1} N/P$_2$0$_5$/S (100%) with 9.2 ton ha^{-1} compost when compared to control.

The increase in plant height with increasing rate of NPS fertilizer and compost could be due to their synergistic effects. Nitrogen is considered as one of the major limiting nutrients in plant growth and adequate supply of it promotes the formation of chlorophyll which in turn resulted in higher photosynthetic activity, vigorous vegetative growth and taller plants. P is required for shoot and root development where metabolism is high and cell division is rapid. Similarly, sulfur in blended NPS fertilizer promotes formation of chlorophyll, higher photosynthetic activity, vigorous vegetative growth and taller plants (Rao et al., 2001). Also the compost acted as the store house of different plant nutrients, reduce P fixation, and improve CEC, aeration, root penetration and water storage capacity of the soil (Rahman et al., 2012).

These results were in line with the findings of Adekayode and Ogunkoya (2010) who explained that there was highly significant difference in maize plant height in plots treated with high fertilizers compared with nil application. Similar results were reported by Ghafoor and Akhtar (1991) who stated that application of high N rates had significant effect on plant height of maize. Also Kumar et al. (2005) reported the highest plant height was recorded from application of 100% NPK (120N:26.2P:33.2K) with 10 ton FYM ha^{-1} over control.

Table6. *Interaction effects of NPS fertilizer and compost on days to 90% maturity and plant height at Jimma in 2017*

$N/P_2O_5/S$ (Kg ha^{-1})	Days to maturity					Plant height (cm)				
	Compost (ton ha^{-1})									
	0	2.3	4.6	6.9	9.2	0	2.3	4.6	6.9	9.2
0/0/0	153.0^{a}	152.7^{a}	150.7^{ab}	149.0^{c}	146.7^{cd}	158.2^{g}	168.9^{g}	195.0^{f}	195.9^{f}	211.00^{def}
23/17.25/3.2	145.7^{de}	145.0^{def}	144.3^{d-g}	144.7^{d-g}	144.7^{d-g}	208.5^{ef}	209.4^{ef}	221.1^{b-e}	220.8^{b-e}	224.4^{a-e}
46/34.5/6.4	144.3^{d-g}	144.0^{efg}	143.7^{efg}	143.3^{efg}	143.0^{fg}	214.7^{c-f}	219.6^{b-e}	222.1^{b-e}	226.5^{a-e}	232.8^{abc}
69/51.75/9.6	144.0^{efg}	143.3^{efg}	143.3^{efg}	143.0^{fg}	142.7^{fg}	227.0^{a-e}	231.2^{a-d}	236.0^{ab}	236.7^{ab}	236.4^{ab}
92/69/12.8	143.0^{fg}	142.7^{fg}	142.7f^{g}	142.3^{g}	142.3^{g}	230.4^{a-d}	236.9^{ab}	236.8^{ab}	239.4^{ab}	242.8^{a}
Mean	144.96					219.29				
LSD (0.05)	2.447					20.265				
CV (%)	0.81					5.64				
F-test	*					**				

Note: *LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.*

Leaf Area Index (LAI)

Leaf area index was highly significantly (P <0.01) affected by the interaction of NPS fertilizer and compost, and also the main effect of NPS fertilizer and compost (Table 9). Numerically, treatment combination of 92/69/12.8 kg ha^{-1} $N/P_20_5/S$ (100%) and 9.2 ton ha^{-1} (100%) compost were gave higher LAI (3.61). But its effect was not statistically significant from combined application of 92/69/12.8 kg ha^{-1} $N/P_20_5/S$ (100%) with 6.9 and 4.6 compost ton ha^{-1}, 69/51.75/9.6 kg ha^{-1} $N/P_20_5/S$ (75%) with 9.2 and 6.9 ton ha^{-1} compost. On other hand, the lowest LAI (1.72) was obtained from the control treatment (Table 7). The LAI was increased by 15.33% and 109.88% at 92/69/12.8 kg ha^{-1} $N/P_20_5/S$ (100%) combined with 9.2 ton ha^{-1} compost when compared with full rate of NPS fertilizer only and control respectively.

The leaf area index was increased with increased NPS fertilizer and compost rate because of vigorous growth of the crop and leaf expansion in length and width. Also, an increase of LAI could be attributed to more production of leaves with expanded leaves produced in response to nitrogen. Phosphorous promotes rapid canopy development and contributing to root cell division. Sulfur also involved in various metabolic and enzymatic processes including photosynthesis and respiration (Rao *et al*., 2001). The compost possibly improved soil physical properties such as bulk density and porosity, moisture holding capacity there by, promoted early root growth, which enhanced ability of plants to access nutrients and promotes leaf area expansion and more number of leaves per plant.

These findings were in agreement with Mahmood *et al.* (2017) who investigated that integrated use of chemical fertilizer with poultry manure (NPK150-85-50 + 7.0 ton ha^{-1}) resulted in maximum LAI. Kumar *et al.* (2005) reported that the maximum leaf area index was recorded from application of 100% NPK (120N:26.2P:33.2K) with 10 ton FYM ha^{-1} over control. Greater LAI in NPK + FYM treatment was attributed to production of new leaves and also increase in size of the existing leaves (Bandyopadhyay *et al.*, 2010).

Number of Leaves per Plant

Number of leaves per plant was significantly (P <0.05) affected by the interaction of NPS fertilizer and compost, whereas highly significantly (P <0.01) affected by the main effect of both NPS fertilizer and compost (Table 9). Plot that received combined application of 92/69/12.8 kg ha^{-1} $N/P_20_5/S$ (100%) with 4.6 ton ha^{-1} (50%) compost showed the highest leaf number (15.47). But its effect was not significantly different from combined application of 92/69/12.8 kg ha^{-1} $N/P_20_5/S$ with 9.2, 6.9 and 2.3 ton ha^{-1} compost; 69/51.75/9.6 kg ha^{-1} $N/P_20_5/S$ with all compost rates except no input of compost, and 46/34.5/6.4 kg ha^{-1} $N/P_20_5/S$ with 9.2 compost ton ha^{-1}. The lowest leaf number (12.40) was recorded from the control, which was not significantly different from 2.3 ton ha^{-1} compost alone (Table 7). The combined application of 92/69/12.8 kg ha^{-1} $N/P_2O_5/S$ (100%) with 4.6 ton ha^{-1} (50%) compost increased the number of leaves per plant by 24.76% and 4.98% when compared with the control and full NPS fertilizer without compost respectively.

Table7. *Interaction effects of NPS fertilizer and compost on number of leaves per plant and leaf area index at Jimma in 2017*

$N/P_2O_5/S$ (Kg ha^{-1})	Number of leaves $plant^{-1}$					LAI				
	Compost (ton ha^{-1})									
	0	2.3	4.6	6.9	9.2	0	2.3	4.6	6.9	9.2
0/0/0	12.40^{g}	12.80^{g}	14.13^{ef}	14.03^{f}	14.20^{ef}	1.72^{l}	2.02^{k}	2.34^{ij}	2.28^{j}	2.63^{h}
23/17.25/3.2	14.13^{ef}	14.23^{ef}	14.27^{ef}	14.63^{c-f}	14.63^{c-f}	2.59^{hi}	2.94^{efg}	2.95^{efg}	2.90^{fg}	2.97^{efg}
46/34.5/6.4	14.33^{def}	14.60^{c-f}	14.70^{cde}	14.77^{b-e}	15.23^{abc}	2.79^{gh}	2.91^{efg}	3.17^{cde}	3.09^{def}	3.33^{bcd}
69/51.75/9.6	14.63^{c-f}	14.93^{a-d}	15.03^{abc}	15.43^{a}	15.37^{ab}	3.07^{def}	3.12^{c-f}	3.15^{c-f}	3.45^{ab}	3.38^{abc}
92/69/12.8	14.67^{c-f}	15.13^{abc}	15.47^{a}	15.40^{ab}	15.40^{ab}	3.13^{c-f}	3.11^{def}	3.48^{ab}	3.55^{ab}	3.61^{a}
Mean	14.58					2.95				
LSD (0.05)	0.658					0.255				
CV (%)	2.42					4.18				
F-test	*					**				

Note: *LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.*

An increase in the number of leaves could positively affect the photosynthetic activity of the plant since leaf number is a growth index that could enhance crop yields. Higher photosynthetic activity and chlorophyll synthesis due to N, P and S nutrients with combined application of compost seemed to have a favorable effect on number of leaves per plant. The reduction of leaf number with low nutrient management might be due to high nutrient use of the crop for vigorous growth. These findings were in line with Qasim *et al.* (2001) who reported that the higher rates of the soil amendments produced more leaves per plant. Also Uwah *et al.* (2011) reported that the highest number of green leaves were recorded under 10 ton ha^{-1} poultry manure and 80 kg ha^{-1} N and lowest under control plots. Adamu *et al.* (2015) also reported that highest number of leaves (10.50) was achieved with application of 150 kg N ha^{-1} + 80 kg P ha^{-1} + 10 ton FYM ha^{-1}.

Stem Diameter (Stem Girth)

The stem girth was significantly ($P < 0.05$) affected by the interaction of NPS fertilizer and compost, and highly significantly ($P < 0.01$) affected by both main effects of NPS fertilizer and compost (Table 9). The highest stem diameter of 2.49 cm was recorded from combined application of 69/51.75/9.6 kg ha^{-1} $N/P_2O_5/S$ (75%) and 9.2 ton ha^{-1} (100%) compost. Whereas, the lowest stem diameter (1.71cm) was obtained from the control, which statistically at par with 2.3 ton ha^{-1} (25%) compost (Table 8). The stem girth at combined application of 69/51.75/9.6 kg ha^{-1} $N/P_2O_5/S$ (75%) and 9.2 ton ha^{-1} (100%) compost was 45.61% thicker than the control. The significant difference among treatments might be attributed to application of nutrients from both NPS fertilizer and compost which enhanced vegetative growth of crop and have a positive effect on maize stem girth. These findings were in line with findings of Adamu *et al.* (2015) who reported that highest stem girth (4.90 and 5.85 cm) were achieved with application of 150 kg N ha^{-1} + 80 kg P ha^{-1} + 10 ton FYM ha^{-1} in 2014 and 2015 respectively and the control had the lowest stem girth. Also Gonzalez *et al.* (2001) reported that NPK (15-15-15 kg ha^{-1}) fertilizer and organic manure which was supplied as essential nutrition at initial establishment stage recorded the best results for width of the stem.

Table8. *Interaction effects of NPS fertilizer and compost on maize stem diameter at Jimma in 2017*

$N/P_2O_5/S$ (Kg ha^{-1})	**Stem diameter (cm)**				
	Compost (ton ha^{-1})				
	0	2.3	4.6	6.9	9.2
0/0/0	1.71^{f}	1.89^{f}	2.20^{de}	2.16^{e}	2.20^{de}
23/17.25/3.2	2.27^{bcde}	2.24^{cde}	2.36^{abcd}	2.34^{abcde}	2.34^{abcde}
46/34.5/6.4	2.26^{cde}	2.33^{abcde}	2.26^{cde}	2.29^{bcde}	2.43^{abc}

69/51.75/9.6	2.22 de	2.23 de	2.32 abcde	2.37 abcd	2.49 a
92/69/12.8	2.33 abcde	2.37 abcd	2.37 abcd	2.43 ab	2.46 ab
Mean	2.28				
LSD (0.05)	0.198				
CV (%)	4.88				
F-test	*				

Note: *LSD = Least Significant Difference; CV = Coefficient of Variation; Means values followed by the same letter(s) within the column are not significantly different at 0.05 probability level.*

Table9. *Main effect of NPS, Compost and interactive effect of NPS and Compost on phonological and growth parameters of maize.*

Parameters	NPS	Compost	NPS*Compost	MS of error
Days to 50% tasseling	**	**	*	0.9717
Days to 50% silking	**	**	**	1.3711
Days to 90% maturity	**	**	*	1.3928
Plant height	**	**	**	152.6968
Leaf area index(LAI)	**	**	**	0.0152
Number of leaves per plant	**	**	*	0.1242
Stem diameter (girth)	**	**	*	0.0123

Note: **, ** = Significant at 5% and 1% level of probability, respectively; MS= mean square*

Conclusion

The current study was initiated with the objectives to investigate the effect of integrated application of NPS fertilizer and compost on phenology and growth parameters of quality protein maize at Jimma, southwestern Ethiopia. The results revealed that individual as well as combined application of NPS fertilizer and compost improved phenology and growth components of the crop. The improvement was mainly due to availability of nutrients from both sources, for plant growth and vegetative performance. The results of phenology and growth parameters indicated the fertility of the soil at experimental area was low, because all fertilized treatments (NPS fertilizer, compost or combinations of the two) gave higher vegetative performance than the control which gave very low vegetative performance. Combined application of NPS fertilizer and compost gave better result than application of either of one. This indicated integrated nutrient management is the best approach for growth and vegetative performance of the crop and soil fertility management. Based on the results of the present study, the combined application of 69/51.75/9.6 kg ha-1 N/P205/S with 6.9 ton ha-1 compost can be used for promoting vigorous maize growth and development.

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