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Integrated Use of Organic and Inorganic Source Fertilizers to Improve Yield of Potato and Soil Properties of Nitisols, Central Highlands Ethiopia

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Abstract: The field experiment was conducted to determine the effect of integrated use of organic and inorganic fertilizers on growth and tuber yield of potato (*Solanum tuberosum* L.). The treatment consists of anintegrated use of organic and inorganic source fertilizer. The treatments included ten selected combinations of organic and inorganic nutrient sources, including vermicomposting, compost, nitrogen (N) and phosphorus (P). The design was randomized complete block with three replications. Results showed that potato yield and yield components, were significantly affected by the application of organic and inorganic fertilizer sources. The highest total tuber yield of 32.2 ton ha^{-1} was obtained from the applications of 75 % Rec NP +25 % vermicompost based on the recommended N equivalent and of the recommended N and P fertilizers, followed by 29.3 ton ha^{-1} due to the application of the full recommended inorganic N and P fertilizers. The highest marketable tuber yield of 28.5 ton ha^{-1} was obtained from the applications of 75% recommended NP with 25 % vermicompost based on the recommended N equivalent. Therefore, potato growers can exercises accompanying inorganic fertilizer with organic nutrients is the most suitable opportunity to maximize the production of potato for smallholder farmers to make their food security sustainable.

Key words: Compost · Potato · Total Tuber Yield · Vermicompost

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important food crops in many countries of the world. In volume of production, it is the fourth most important crop in the world after wheat, maize and rice with annual production of 314.1 million tons cultivated on about 18.1 million hectares of land [1]. Potato is regarded as a high-potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle [1]. It is a major part of the diet of half a billion consumers in the developing countries [2]. In Ethiopia, potato (*Solanum tuberosum* L.) has promising prospect in improving the quality of the basic diet in both rural and urban areas. It is an important crop for smallholder farmers in Ethiopia, serving both as a cash crop and food security crop [3]. It is one of the root crops widely grown in the country because of increasing demand and emerging markets that have provided a great opportunity for resource-poor farmers to generate additional income as stated [3, 4]. It is a short duration crop that can mature within short period of time. It contains practically all essential dietary constituents like carbohydrates, essential nutrients, protein, vitamins and minerals [5]. Potato production has been considered as the first priority compared to other food crops because of its contribution to food security, income generation and its utilization in different forms [3].

The gap between the production potential and the current national production average could be attributed to many and complex biotic, abiotic and human factors [6]. Production constraints that have contributed to the limited production of potatoes in Ethiopia include low soil fertility soil and poor soil management practices [7, 8]. Low soil fertility in general and deficiency of Nitrogen (N) and Phosphorus (P) in most Ethiopian soils in particular is the most important constraint limiting potato production in Ethiopia [9, 10]. The authors reported that,

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the soil fertility decline is attributed to continuous cropping, reduced crop rotation, removal of nutrients together with the harvested crops, reduced use of animal manure and crop residues due to their use as a fuel, which should be added to the soil and erosion coupled with low inherent fertilit.

The integrated nutrient management is a strategy that incorporates both organic and inorganic plant nutrients to attain higher crop productivity, prevent soil degradation and thereby help meet future food supply needs due to positive complementarities [11]. The use of both organic and inorganic fertilizers responds positively to improve output markets and crop prices. The profitability of alternative nutrient input sources depends not only on yield gains but also on market condition s. many studies have found that the poor farmers' inability to access mineral fertilizers have adverse consequences on soil fertility and incomes [12].

The combined use of organic and inorganic inputs saves about 50% of the cost of inorganic nitrogen fertilizer on its own [13, 14]. Integrated use of soil management technologies had reduced considerable quantity of inorganic fertilizers and saved costs invested for chemical fertilizers in potato production [15]. Farmers in the study area are aware of the response of potato and other related crops to applied nutrients and raise the crop in the homesteads using cattle manure, household waste etc. However, they do not know the rate of manure and its combined effect with inorganic fertilizers (nitrogen and phosphorus0 for high production of the crop [11]. So far, no information is available and no research has been done on the combined effects of chemical and organic fertilizer requirement. Therefore, this study was initiated with the objective of evaluated the effect of integrated nutrient management on yield and yield components of potato and soil physiochemical properties.

MATERIALS AND METHODS

The experiment was conducted in Welmera, Ada'a Berga and Ejere districts of West Shewa Zone of Oromia National Regional State for three consecutive cropping seasons (2017 -2019). The experiment site is located at 090 03' N latitude and 380 30' E longitude, 30, 40 and 60 km west of Addis Ababa, respectively, at an altitude of about 2400 m above sea level (Fig. 1). The mean annual rainfall of the study area was 1100 mm, of which about 85% falls from June to September and the rest from March to May. According to Holetta Agricultural Research Center Meteorological Report, the mean annual temperature was about 14.3°C, with the mean maximum and minimum temperatures of 21.7°C and 6.9°C, respectively and means relative humidity of 60.6% (16). The environment is seasonally humid and the major soil type is Nitisols [17].

The experiment was laid out in RCBD with three replications. Urea (46-0-0) and TSP was used as source of N and P. TSP fertilizer was applied as basal application at planting and N in urea was applied in split form. Both organic sources materials were applied three weeks before planting. The rate of both organic sources was calculated based on recommended inorganic N fertilizer equivalence.

The field experiment was comprised ten (10) treatments

1	Negative (o)	6	50 % Recommended NP +50 % vermicompost
2	100 % Recommended NP	7	75 % Recommended NP +25 % vermicompost
3	100 % vermicompost	8	75 % Recommended NP +25 % compost
4	100 % compost	9	50 % Recommended NP +50 % compost
5	25 % Recommended NP +75 % vermicompost	10	25 % Recommended NP +75 % compost

Table 1: Result of laboratory analysis of vermicompost and compost before application

Parameter	Vermicompost (%)	Compost (%)
pH	7.3	6.93
Total N (%)	1.03	0.82
Available P (%)	0.63	0.51
Exchangeable K (%)	2.63	2.42
Organic matter (%)	5.56	5.42

Fertilizer (Inorganic): Nitrogen in the form of Urea (46% N) and phosphorous in the form of triple superphosphate (46% P_2O_5) were used as source of N and P, respectively.

Vermicompost and Compost: Well prepared vermicompost and compost were used. Then their pH, N, P, K and organic matter contents were analyzed in the laboratory to determine the rate of application of eachtreatment, which was based on recommended N equivalent rate for the test crop before application.

Data Collection and Analysis: Composite surface soil samples were collected from experimental fields (0-20 cm depth) before treatment application. Similarly, soil samples were also collected after harvest of the crop from each plot and then composited by replication to obtain one representative sample per treatment. The collected samples were analyzed for the determinations of, soil texture, pH, organic carbon (OC), total N, available P and exchangeable k. Soil particle size distribution/ texture were analyzed using the Bouyoucos hydrometer method [18]. The pH of the soil was measured in 1:2.5 (weight/ volume) soil to water ratio using a glass electrode attached to digital pH meter [19]. Soil organic matter was determined by wet oxidation method as described by Bray and Kurtz [20]. Total nitrogen was determined by using Kjeldahl method as described by Jackson [21] and available phosphorus was determined by using the Bray II method Bray and Kleinkopf *et al.*[22] and exchangeable K and was determined from the same extract with flame photometry [23].

Growth Parameters: Average stems number per plant: the actual numbers of main stems per hill were recorded as the average stem count of five hills per plot at 50% flowering. Only stems that emerged independently above the soil as single stems were considered as main stems. Stems branching from other stems above the soil were not considered as main stems.

Plant Height (cm): Was measured by taking five randomly reselected plants per plot as the distance in cm from the soil surface to the top most growth point of aboveground at full maturity.

Total Tuber Number: This was counted as the sum of marketable and unmarketable tubers from the net plot.

Marketable Tuber Yield (ton ha^{-1}): Included marketable and healthy tubers with size categories greater than 25 g.

Specific Gravity of Tubers (g cm^{-3}): To determine the specific gravity, tubers of all size categories weighing about two kilograms were randomly taken from each plot, washed with water. The sample was then first weighed in air and then re-weighed suspended in water. Specific gravity was then determined using the following formula [24].

Specific Gravity = Weight in air
Weight in air--Weight in water

Tuber Dry Matter Content (%): Five fresh tubers were randomly selected from each plot and weighed at harvest. The tubers were then sliced and dried in an oven at 65°C for about 72 hrs until a constant weight is obtained. The dry weight was recorded and the dry matter percent calculated [25].

Dry matter (%) = Weight of sample after drying (g) X100%
Initial weight of sample (g)

Statistical Analysis: Differences between treatments were determined by analysis of variance (ANOVA) using SAS software [26]. Treatment means were compared using least significant differences (LSD) at the 5% level of significance.

RESULTS AND DISCUSSION

Effects of Organic and Inorganic Nutrient Use on Soil Chemical Properties: Soil chemical properties such as pH, organic carbon (OC), N, P and k measured before planting and after harvesting. The result showed that higher pH, total nitrogen (TN) and organic carbon (OC) were recorded from full dose application of compost (Table 3). The lowest soil pH, organic carbon (OC), N, P and k were recorded from the negative control. According to Ferdous *et al.* [27] indicate that integrated application of organic and inorganic nutrient sources has a significant improvement in the condition of the soil and yield productivity.

Effect of Organic and Inorganic Fertilizer on Growth Parameters: The analysis of variance showed that growths parameters, total tuber number and marketable tuber number, were significantly ($P < 0.01$) influenced by integrated application of organic and inorganic fertilizer except Plant height.

Stem Number: Although stem density is one of the most important yield components in potato, the results of the

Table 2: Soil Physico- chemical properties of the experimental site before planting

Soil texture			Soil chemical properties				
Clay (%)	Silt (%)	Sand (%)	pH (H_2O)	OC (%)	TN (%)	Available P (ppm)	Exch.k (meq/100)
70.12	12.23	17.65	4.76	1.12	0.10	7.63	0.28

Table 3: Physico- chemical soil properties of the experimental site after harvesting

	Value of soil parameters				
Treatments	pH (H_2O)	OC (%)	TN (%)	Available P (ppm)	Exch.k (meq/100)
Negative (o)	4.56	1.13	0.12	7.62	0.24
100 % recommended NP	4.82	1.12	0.18	7.23	0.23
100 % vermicompost	5.22	1.23	0. 22	12.13	0.38
100 % compost	5.28	1.56	0.24	11.3	0.43
25 % recommended NP +75 % vermicompost	5.21	1.32	0.21	9.56	0.39
50 % recommended NP +50 %vermicompost	5.13	1.46	0.18	8.96	0.35
75 % recommended NP +25 % vermicompost	4.86	1.54	0.16	9.34	0.41
75 % recommended NP +25 % compost	4.92	1.42	0.14	10.23	0.42
50 % recommended NP +50 % compost	4.78	1.63	0.22	10.10	0.37
25 % recommended NP +75 % compost	4.87	0.20	15.02	11.23	0.36

Table 4: Effect of organic and inorganic fertilizer on potato growths parameters

Fertilizer rate (kg ha^{-1})	Stem number per hill	Plant height (cm)	Number of stand count
Negative (o)	2.13b	36.9	28.0b
100 % Rec NP	2.45ab	34.33	31.0ab
100 % VC	2.60ab	39.7	30.67ab
100 % compost	2.67ab	37.0	32.3ab
25 % Rec NP +75 % VC	2.53ab	34.4	28.67b
50 % Rec NP +50 % VC	2.67ab	34.2	30.0ab
75 % Rec NP +25 % VC	2.8ab	35.13	31.0ab
75 % Rec NP +25 % comp	2.33 b	37.93	30.0ab
50 % Rec NP +50 % comp	3.13a	36.47	31.34ab
25 % Rec NP +75 % comp	2.8ab	36.67	33.67a
LSD (0.05)	0.76	NS	4.94
CV (%)	16.98	14.78	9.26

Note: Means of the same letter within a column are not significantly different at 5% level of significance. NS, non-significant at $P < 0.05$ probability level; LSD, least significant difference; CV, Coefficient of Variation

present study showed that the influences of organic and inorganic fertilizer on stem number. The highest (2.8) stem number /stem density) was recorded from application of 75 % Rec NP +25 % vermicompost (Table 4).

Plant Height (cm): Application of integrated organic and inorganic fertilizer had no a significant effect on plant height (Table 4). The tallest plants were obtained in the response to applying the full dose (100%) of vermicompost based on N equivalency. The lowest plant height was recorded under the control treatment.

Stand Count at Flowering: The analysis of variance revealed that stand count at flowering was highly significant ($P< 0.001$) due to combined organic and inorganic fertilizer application. The highest (33.67) stand count was recorded from the response of 25 % recommended NP with 75 % compost while, the lowest (28.0) was recorded from the treatment that had not received external nutrients applications (Table 4).

Influence of Organic and Inorganic Fertilizer on Tuber Yields of Potato

Marketable Tuber Number: Marketable tuber number was highly significant ($p<0.01$) and affected by integrated application of organic and inorganic nutrients (Table 5). The highest marketable tuber yield was recorded in the treatment that received the combination of 75% recommended NP with 25% recommended vermicompost based on N equivalent. While, the lowest marketable tuber yield was recorded in the treatment that not received fertilizers. The possible reason for the increment of marketable tuber yield might be due to external combined application of organic and inorganic fertilizer [27].

Table 5: Effect of organic and inorganic fertilizer on tuber yield of potato

Fertilizer rate (kg ha^{-1})	Marketable Tuber Yield (ton ha^{-1})	Total Tuber Yield (ton ha^{-1})	Specific gravity	Dry matter (%)
Negative (o)	13.4d	17.4d	1.022c	22.2b
100 % Rec NP	25.7ab	29.3ab	1.028cb	22.6b
100 % VC	14.99d	20.4cd	1.036b	23.06ab
100 % compost	15.1d	19.5cd	1.032b	23.12ab
25 % Rec NP +75 % VC	18.6cd	24.2bcd	1.048ab	22.81b
50 % Rec NP +50 % VC	18.7cd	25.0abcd	1.042ab	22.84b
75 % Rec NP +25 % VC	28.5a	32.2a	1.054a	23.28a
75 % Rec NP +25 % comp	18.4cd	23.0bcd	1.046ab	23.08ab
50 % Rec NP +50 % comp	19.7bcd	24.0bcd	1.044ab	23.11ab
25 % Rec NP +75 % comp	23.2abc	27.1abc	1.037b	23.02ab
LSD (0.05)	5.7	6.9	0.12	0.28
CV (%)	33.6	32.8	1.22	1.52

Note: Means of the same letter within a column are not significantly different at 5% level of significance. NS, non-significant at $P < 0.05$ probability level; LSD, least significant difference, CV, Coefficient of Variation.

Total Tuber Yield: Total tubers numbers were significantly affected by combined application of organic and inorganic fertilizer (Table 5). The results showed that increasing the combined rate of 75 % Recommended NP with 25 % vermicompost based on N equivalent nutrients markedly increased tuber yields. The result was supported with the findings [28]. As reported by this author's application of organic fertilizer number of tuber production and might be attributed to the role of raising the organic content of soil. The highest and most significant tuber production (marketable and total tuber yield) was found from the plots treated with combination of 75% of the recommended inorganic (NP) fertilizers with 25% vermicompost, while, the lowest one was recorded in the control (without addition of external nutrients).

As the results indicated from Table 5, as combination of organic and inorganic fertilizer increasing total tuber number and, marketable were highly increased, this is due to potato high responsive when compared to other tuber crops [8, 29]. The increased marketable tuber yields due to integrated use of NP and vermicompost for tuber might be related to the increment of soil micro and macro nutrients and its availability to the crop for comfort of abortion [28, 30].

The results of this experiment also confirmed the observations [31, 32] who reported that integration of organic and mineral NP fertilizers sustains crop production due to positive interaction and complementarities between them. The results recorded from these findings confirm the study [33] who reported that who suggested that organic and inorganic mineral inputs cannot be relieved completely by one another and are both required for sustainable crop production. Separately from providing nutrients, vermicompost provides valuable organic matter to help improve soil physico-chemical properties and increase the activity of beneficial soil microbes [34, 35].

CONCLUSIONS

The results of the present study confirmed that the integrated use of 75 % recommended NP with 25 % vermicompost fertilizers significantly improved potato tuber yield as compared to the use of each fertilizer source separately, thus potentially reducing the cost of production. The option of prepared75 % of the recommended inorganic fertilizers with the application of 25 % vermicompost, as observed in the present study must be a great benefit to those farmers with sufficient producing vermicompost. Furthermore, the integrated approach has a long-term benefit in that it also improves the physico-chemical properties of the soil for sustainable crop production.

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REFERENCES

1. Adane Hirpha, M.P.M. Meuwissen, Agajie Tesfaye, W.J.M. Lommen, A.O. Lansink, Admasu Tsegaye and P.C. Struik, 2010. Analysis of Seed Potato Systems in Ethiopia. American Potato Journal, 87: 537-552.
2. Mondal, M.A., A. Islam, M.R. Hossain, M. Mahmud and M.K. Islam, 2004. Genetic variability and path coefficient analysis of exotic varieties of potato. Bangladesh Journal of Plant Breeding and Genetics, 17(2): 47-50.
3. Bezabih Emana and Hadera Gebremedhin, 007. Constraints and opportunities of Horticulture production and marketing in Eastern Ethiopia. The Dry lands Coordination Group Report, 46: 19-21.
4. Wudineh Getahun Abebe Chindi and Gebremedhin W/Giorgis, 2017. Technical Efficiency Analysis for Rain-fed and Irrigated Smallholder Potato (*Solanum tuberosum* L.) Production in Welmera district, Oromia, Ethiopia. Journal of Development and Agricultural Economics, 9(8): 217-223.
5. Abebe Chindi, Gebremedhin W/Giorgis, Atsede Solomon, Lemma Tessama and Kassaye Negash. 2014. Rapid Multiplication Techniques (RMTs): A Tool for the Production of Quality Seed Potato (*Solanum tuberosum* L.) in Ethiopia. Asian Journal of Crop Sciences, 6(3): 176-185, 2014.
6. Egata Shunka, Abebe Chindi, Gebremedhin W/giorgis, Ebrahim Seid and Lemma Tessema, 2017. Determination of Optimum Nitrogen and Potassium Levels for potato Production in Central high lands of Ethiopia. Open Agriculture, 2: 189-194.
7. Shunka, E., A. Chindi, G. W/giorgis, E. Seid and L. Tessema, 2016. Response of Potato (*Solanum tuberosum* L.) Varieties to Nitrogen and Potassium Fertilizer Rates in Central Highlands of Ethiopia. Adv. Crop. Sci. Tech., 4: 250. doi:10.4172/2329-8863.1000250.
8. Simon Koroto, 2019. Effect of Farmyard Manure and Mineral NP Fertilizers on Yield Related Traits and Yield of Potato (*Solanum tuberosum* L.) at Areka, Southern Ethiopia. International Journal of Horticultural Science and Ornamental Plants, 5(1): 074-085.
9. Niguse, M.A., 2016. Effect of phosphorus and potassium fertilizer rates on yield and yield component of potato (*Solanum tubersum* L.) at K/ Awlaelo, Tigray, Ethiopia. Food Science and Quality Management, 48: 60-69.
10. HARC (Holetta Agricultural Research Center), 2017/2018. Agrometeorological data annual progress Report, Holeta, Ethiopia.
11. IUSS (International Union of Soil Sciences) Working Group WRB, 2006. World reference base for soil resources. World Soil Resources Reports No. 103. FAO, Rome.
12. Akinola, A.A., A.D. Alene, R. Adeyemo, D. Sanogo and A.S. Olanrewaju, 2009. Economic impacts of soil fertility management research in West Africa. Africa J.Agri. Res., 3(2): 159-175.
13. Bouyoucos, J., 1962. Hydrometer method improved for making particle size analysis of soil. Agronomy Journals, 54: 464-465.
14. Gezahegn Garo, Andergachew Gedebo and Kelsa Kena, 2014. Combined effects of inorganic (NP) and farm yard manure (FYM) fertilizers on root yield and above ground biomass of sweet potato (Ipomoea batatas (L.) lam.) at Delbo watershed Wolaita zone, Southern Ethiopia. Journal of Scientific Research and Reviews, 3(2): 028-033, March 2014.
15. Tolera, A., 2016. Maize Response to Fertilizer Application in Ethiopia. Ethiopian Journal of Natural Resource, 16(1&2): 25-41.
16. Page, A.L., 1982. Methods of soil analysis. Part 2. Chemical and Microbiological Properties.
17. Vanlauwe, B., K. Aihou, S. Aman, E.N.O. Iwuafor, B. Tossah, J. Diels, N. Sanginga, O. Lyasse, R. Merckx and S. Deckers, 2001. Maize yield as affected by organic inputs and urea in the West African moist savanna. Agron. J., 93: 1191-9.
18. Walkley, A. and I.A. Black, 1934. An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. Soil Science, 37: 29-38.
19. Jackson, M.L., 1967. Soil Chemical Analysis. Prentice-Hall of India, New Delhi.
20. Bray, R.H. and L.T. Kurtz, 1945. Determination of total organic and available phosphorus in soils. Soil Science, 59: 39-45.
21. Chapman, H.D., 1965. Cation exchange capacity by ammonium saturation. 9: Inc 891-901.
22. Kleinkopf, G.E., D.T. Wester Mann and M.J. Willie, 1987. Specific gravity of Russet Burbank potatoes. American Potato Journal, 64: 579-587.
23. SAS, 2004. SAS/STAT User's Guide, Version 9.0. SAS institute Inc., Cary and NC.USA.
24. William, M.A. and G.W. Woodbury, 1968. Specific gravity dry matter relationship and reducing sugar changes affected by potato variety, production area and storage. American Potato Journal, 45(4): 119-131.

25. Chen, J.H., J.T. Wu and W.T. Huang, 2001. Effect of Compost on the Availability of Nitrogen and Phosphorus in Strongly acidic Soils. Department of Soil and Environmental Science, National Chung-Hsing University Taichung, Taiwan ROC.
26. Daniel, M., L.M. Pant and Nigussie Dechassa, 2008. Effect of integrated nutrient management on yield of potato and soil nutrient status of Bako, West Shewa. Ethiopian Journal of Natural Resources, 10: 85-101.
27. Ferdous, Z., M. Anwar, M.A. Rahman, F. Yasmine and J. Nain, 2011. Fertilizer management for potato mungbean-T. aman based cropping pattern. Journal of Agroforestry and Environment, 5: 129-132.
28. Gedam, V.B., J.R. Rametke, Rudragouda and M.S. Power, 2008. Influence of organic manures on yield, nutrient uptake and change in physico-chemical properties of soil after harvest of groundnut. Crop Research, 36: 111-114.
29. Gezahegn Garo, Andergachew Gedebo and Kelsa Kena, 2014. Combined effects of inorganic (NP) and farm yard manure (FYM) fertilizers on root yield and above ground biomass of sweet potato (*Ipomoea batatas* (L.) lam.) at Delbo watershed Wolaita zone, Southern Ethiopia. Journal of Scientific Research and Reviews, 3(2): 028-033, March 2014.
30. Girma Chala, Daniel Muleta and Zeleke Obsa, 2020. Combination of Organic and Inorganic Fertilizer Improves Malt Barley Yields, Quality and Soil Properties on Nitisols of Central Highlands of Ethiopia. American-Eurasian J. Agric. & Environ. Sci., 20(3): 176-183 2020 ISSN 1818-6769.
31. Habtam Setu, Nigussie Dechassa and Yibekal Alemayehu, 2018. Influence of phosphorus and potassium fertilizers on growth and yield of potato (*Solanum tuberosum* L.) at Assosa, Benishangul Gumuz Regional State and Western Ethiopia. Journal of Soil Science and Environmental Management. http://www.academicjournals.org/JSSEM, 9(6): 81-90, June 2018.
32. Melkamu Workineh, Nigussie Dechassa and J.J. Sharma, 2019. Influence of Integrated Fertilizer Application on Growth and Tuber Yield of Potato (*Solanum tuberosum* L.) in Haramaya District, Eastern Ethiopia. World Journal of Agricultural Sciences, 15(6): 380-395, 2019 ISSN 1817-3047.
33. Koroto, S., 2019. Effect of Farmyard Manure and Mineral NP Fertilizers on Yield Related Traits and Yield of Potato (*Solanum tuberosum* L.) at Areka, Southern Ethiopia. International Journal of Horticultural Science and Ornamental Plants, 5(1): 074-085.
34. Place, F., B. Christopher, B. Barrett, A. Freeman, D. Bernard and D. Vanlauwe, 2003. Prospects for integrated soil fertility management using organic and inorganic inputs: Evidence from smallholder African agricultural systems. Food Policy, 8: 365-378.
35. Tesfaye Balemi, 2012. Effect of integrated use of cattle manure and inorganic fertilizers on tuber yield of potato in Ethiopia. Journal of Soil Science and Plant Nutrition, 12(2): 253-261.