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Growth, Yield and Plant Quality of Sweet Basil (*Ocimum Basilicum* L.) as Affected by Nitrogen and Potassium Doses Under Neutral and Acidic Soil Condition

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ABSTRACT

Considering the great significance of basil for food and medicinal purposes, it is important to study the proper culture and management of sweet basil. A pot experiment was done to: (a) evaluate the effects of increasing doses of nitrogen and potassium application on the growth, yield, and plant quality of sweet basil; (b) determine the optimum rate of nitrogen and potassium combination for sweet basil and (c) assess the effects of different levels of nitrogen and potassium fertilizers on the chemical properties of acidic and neutral soil. There were eight treatments consisting of different levels of N and K_2O added into neutral and acidic soil. These treatments were the following: T_1 – Control (No fertilizer), T_2 - 60-60-60 kg/ha N-P_2O_5-K_2O (RR), T_3 – 0- 60- 60 kg/ha N-P_2O_5- K_2O, T_4 – 120-60-60 kg/ha N-P_2O_5- K_2O, T_5 – 180-60-6/h0 kg/ha N-P_2O_5- K_2O, T_6 – 60-60-0 kg/ha N-P_2O_5- K_2O, T_7– 60-60-120 kg/ha N-P_2O_5- K_2O, and T_8 – 60-60-180 kg/ha N-P_2O_5- K_2O.

The results showed that the application of T_3 (0-60-60 kg/ha N-P_2O_5-K_2O) has increased plant height, number of primary branches, root length, fresh and dry weights of leaf, herbage yield, and root weight under neutral soil condition. Meanwhile, optimum application of N and K (60-60-60 kg/ha N-P_2O_5- K_2O) influenced sweet basil's quality in terms of its chlorophyll content (Chlorophyll a and b). Moreover, increased chemical properties of neutral and acidic soil were significantly affected by application of T_5 (180-60-60 kg/ha N-P_2O_5- K_2O), T_7 (60-60-120 kg/ha N-P_2O_5- K_2O), and T_8 (60-60-180 kg/ha N-P_2O_5- K_2O). Most importantly, application of T_3 (0- 60- 60 kg/ha N-P_2O_5- K_2O), T_4 (120-60-60 kg/ha N-P_2O_5- K_2O), T_6 (60-60-0 kg/ha N-P_2O_5- K_2O), and T_8 (60-60-180 kg/ha N-P_2O_5- K_2O) has influenced % N, P, and K concentrations in basil leaf significantly. The optimum combination of N and K that was highly favorable under both neutral and acidic condition was T_3(0-60-60 kg/ha N-P_2O_5-K_20), indicating that sweet basil needs small amounts of N for its growth and yield.

Keywords: sweet basil, Nitrogen, Potassium, neutral and acidic soil

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INTRODUCTION

Sweet basil (*Ocimum basilicum* L.) is an important aromatic plant cultivated in many parts of the world for its essential oil. Some of the more popular basils include sweet, specialty fragrant (cinnamon, lemon and Thai/anise), purple-leaved, bush, and miniature or dwarf. Holy basil in particular has been found to reduce circulating glucose levels in both normal and diabetic laboratory animals as well as in diabetic humans. These results, particularly the evidence from human experiments, are hopeful and could add credibility to the medicinal use of basil in ancient cultures (Centers for Disease Control and Prevention 2008). However, a study on the cultural management of this plant, specifically on its nutrient requirements and the types of soils that are suitable for its growth and development, has not been conducted. This is a novel development which needs to be supported by the latest agricultural innovations.

In recent years, innovations and researches are mainly focused on the tremendous development of high yielding varieties. However, majority of the farmers have still been producing yields way below than what has been obtained in research stations. As a result, the farmers' produce has decreased while demand for food has increased rapidly due to rapid growth of population and accessibility to food. These reasons are attributed to unfavorable climate conditions and improper or insufficient cultural management techniques (i.e control of pest and diseases and fertilizer application). Most farmers and growers lack the technical know-how with regards to proper use and handling of fertilizers which often result to continuous depletion of the essential elements needed by plants such as nitrogen (N), phosphorus (P) and potassium (K) and other micronutrients thus, optimum rate for fertilization is required to augment its production (Cabanilla 1996; O'Sullivan et al 1997).

Nitrogen, which is called a yield-stimulating nutrient, affects both volumes of yields and the chemical composition of yield components (Chen et al 2004; Nurzyñska-Wierdak, 2006; Biesiada & Kuœ, 2010). The effective use of N fertilizers to achieve maximum yields while reducing the amount of nitrate-N in the soil is very important in both developed and developing countries (Ankumah 2003).

Aside from N, potassium (K) is considered as an essential plant nutrient which is commonly lacking in many fields. According to Matsumoto et al (2013), increasing potassium doses contributed to the elevation of protein and total nitrogen concentration, as well as decreased the ammonium and nitrate nitrogen in basil.

Considering the great significance of basil for food and medicinal purposes, it is important to study the proper culture and management of sweet basil. This will pave the way for its massive cultivation to meet the high demand for the crop. In VSU, there has been no study focusing on the cultural management of sweet basil, specifically on its nutrient and soil type requirements as well as its effects on the growth, yield, and quality. Thus, this study was conducted to: (a) evaluate the effects of increasing doses of nitrogen and potassium application on the growth, yield, and plant quality of sweet basil; (b) determine the optimum rate of nitrogen and potassium combination for sweet basil and; (c) assess the effects of different levels of nitrogen and potassium fertilizers on the chemical properties of acidic and neutral soil.

MATERIALS AND METHODS

Soil Chemical Analysis

Bulk samples of acidic and neutral soil were collected from the surface (0-20 cm layer) at two different locations of the Visayas State University, Visca, Baybay City, Leyte. The samples were thoroughly mixed, sterilized, and sieved with a 10 mm wire screen to remove gravel and big root fractions. Composite soil samples of about 1 kg were collected, air-dried, pulverized, and sieved using 2-mm wire mesh. This served as the initial composite sample and submitted to the Central Analytical Service Laboratory (CASL), Philippine Root Crop Research Center (PhilRootcrops), VSU, Visca, Baybay City, Leyte for analysis of the following parameters: soil pH (Potentiometric method using 1:2.5 soil water ratio ISRIC 1995), organic matter (%) (Modified Walkley Black Method, Nelson and Sommers 1982), total N (%) (Kjedahl Method, USDA 2004), available phosphorous (Bray No. 2 Method, Jackson 1958), and exchangeable K (extracted using 1 N NH_4OAc and quantified by the used of Atomic Absorption Spectrophotometer Varian 220 FS). After harvest, the soil samples were collected from each pot. These were air-dried, sieved, and analyzed for the determination of the same soil parameters mentioned above.

Experimental Design and Treatments

The pot experiment was conducted at the Department of Soil Science (DSS) screenhouse to protect plant samples from excessive rainfall at Visca, Baybay City, Leyte. The experiment was carried out in Factorial arranged in Randomized Complete Block Design with eight (8) treatments, replicated three (3) times with three (3) sample plants in each replication. The different treatment combinations were designated as follows: Factor A: Main Plot (Type of Soil) (a) M_1 = Acidic Soil (b) M_2 = Neutral Soil and Factor B: Sub-plot (N and K_2O levels), T_1 – Control (No fertilizer), T_2 - 60-60-60 kg/ha N-P_2O_5- K_2O (RR), T_3 – 0- 60- 60 kg/ha N-P_2O_5- K_2O, T_4 – 120-60-60 kg/ha N-P_2O_5- K_2O, T_5 – 180-60-60 kg/ha N-P_2O_5- K_2O, T_6 – 60-60-0 kg/ha N-P_2O_5- K_2O, T_7 – 60-60-120 kg/ha N-P_2O_5- K_2O and T_8 – 60-60-180 kg/ha N-P_2O_5- K_2O. The pot distance was 0.4 m x 0.4 m.

Cultural Management Practices

Three seeds of sweet basil (var. Genovese) were sown in each cell in the propagation tray. Partial shading was done to minimize the exposure of seedlings to direct sunlight. Thinning was done as the seedlings emerged (three pairs of leaves). After 15 days, transplanting was done leaving one healthy seedling per pot. A total of 144 polyethylene pots, with five (5) perforations at the bottom were used and placed at the DSS screen house. Each pot was filled with 3 kg of air-dried soils (acid and neutral soil). Sufficient amount of water was added to keep the moisture at field capacity.

Urea (46-0-0), solophos (0-20-0), and muriate of potash (0-0-60) are commercially available inorganic fertilizers. In order to satisfy the recommended rate of sweet basil at 60-60-60 kg N-P_2O_5-K_2O per ha, a corresponding amount of 3.91-9.00 -3.00 g per pot of urea, solophos, and muriate of potash were added.

All fertilizers were added to the pots two (2) weeks after transplanting by boring four (4) holes around each plant (Table 1).

Insecticide and fungicide were sprayed at weekly intervals when mechanical damage and fungal diseases on sweet basil were found and identified. Spraying was done starting from one week after transplanting up to the plants' first flowering. Weeds were removed regularly by hand. The experimental plants were watered at field capacity to avoid waterlogging of pots.

The first harvest was done 54 days from transplanting. Once the plants have developed six to eight pairs of true leaves, harvesting may begin. Sweet basil plants were cut 1 cm above the ground. The stem, leaves, and roots were separated. These were washed with tap water, then distilled water, and were blotted dry and weighed for fresh plant biomass. At harvest, plant leaves were weighed, then placed in labelled paper bags for oven drying at 70º C for three (3) days or until constant weight was attained. After which, these were weighed again to get the dry matter weight and ground to a particle size of 1 mm using a Wiley Mill Grinder. The ground tissue samples were used to determine total N (%), total P (%), and total K (%).

Table 1. Amount of fertilizer added in each pot

	FERTILIZER (g/ pot)		
T_1 – Control (No fertilizer)	0.00	0.00	0.00
T_2 – 60- 60- 60 kg/ha N-P_2O_5-K_2O	3.91	9.00	3.00
T_3 – 0- 60- 60 kg/ha N-P_2O_5-K_2O	0.00	9.00	3.00
T_4 – 120- 60- 60 kg/ha N-P_2O_5-K_2O	7.83	9.00	3.00
T_5 – 180- 60- 60 kg/ha N-P_2O_5-K_2O	11.74	9.00	3.00
T_6 – 60- 60- 0 kg/ha N-P_2O_5-K_2O	3.91	9.00	0.00
T_7 – 60- 60- 120 kg/ha N-P_2O_5-K_2O	3.91	9.00	6.00
T_8 – 60- 60- 180 kg/ha N-P_2O_5-K_2O	3.91	9.00	9.00

Data Gathered

Growth, yield, and plant quality parameters were gathered. These were plant height (cm), number of primary branches per plant, root length (cm), fresh leaf weight/plant (g/pot), dry leaf weight/plant (g/pot), fresh herbage yield at harvest (g/pot), dry matter at harvest (g/pot), fresh root weight (g/pot), dry root weight (g/pot), chlorophyll contents (SPAD Chlorophyll meter, Minolta Brand), and chlorophyll A and B contents analysis (Porra et al 1989).

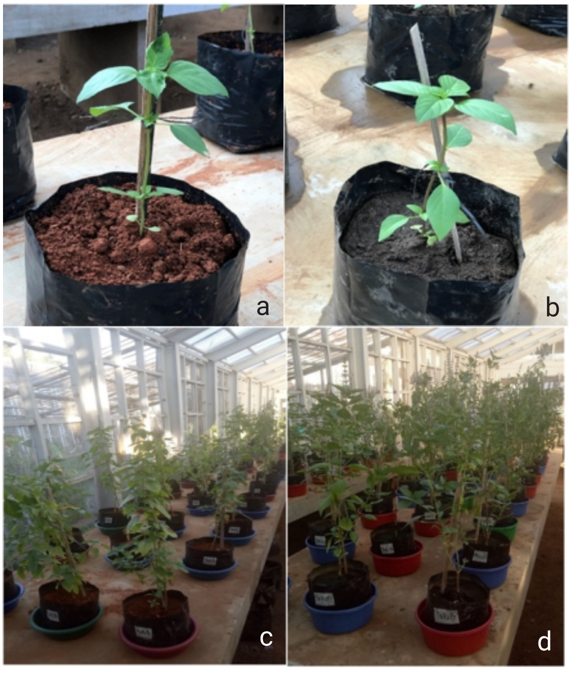
Statistical Tool

All the data were encoded in Microsoft Excel and subjected to statistical analysis of variance (ANOVA) using Statistix Software (ver 8.1). If found significant, treatment means were separated using the Honest Significant Difference or Tukey's test at 5% Level of Significance.

RESULTS AND DISCUSSIONS

General Observations

One week after transplanting, sweet basil planted on acidic and neutral soil applied with different levels nitrogen and potassium fertilizers were more or less the same in terms of growth (e.g. plant height) as shown in Figure 1a. At the later stage of growth (weeks 3-7), a considerable increase in height was observed in plant samples supplied with optimum amount of inorganic fertilizer (Fig. 1b). Moreover, yellowing of leaves was noted in plants grown under acidic and neutral soil without any fertilizer (e.g. control and T_3). Symptoms of chlorosis were also observed in some of the plant samples (T_1, T_5, and T_8). Signs of larval infestation were also observed randomly among the plants. However, three weeks after transplanting, severe yellowing of leaves and wilting were observed particularly in the plants without any fertilizer (i.e. control) and with the highest dose of N and K (T_5 and T_8).



Legend:

T_1 – Control (No fertilizer)
T_2 – 60- 60- 60 kg/ha N-P_2O_5-K_2O
T_3 – 0- 60- 60 kg/ha N-P_2O_5-K_2O
T_4 – 120- 60- 60 kg/ha N-P_2O_5-K_2O
T_5 – 180- 60- 60 kg/ha N-P_2O_5-K_2O
T_6 – 60- 60- 0 kg/ha N-P_2O_5-K_2O
T_7 – 60- 60- 120 kg/ha N-P_2O_5-K_2O
T_8 – 60- 60- 180 kg/ha N-P_2O_5-K_2O

Figure 1. Sweet basil grown in acidic and neutral soil at 1 week after transplanting (WAT- (a) & (b)) and at harvest ((c)& (d))

Effects of Nitrogen and Potassium on the Growth of Sweet Basil

a. Plant Height

Figure 2a shows the plant height of sweet basil at harvest under acidic and neutral soil as affected by different levels of N and K fertilizers. The results showed that a constant increase in plant height from week 1 to 7 was observed in plants under neutral soil condition, specifically $T_{3,}$ T_2, T_6, T_7, and acidic condition (T_3). Sweet basil planted on neutral soil had the highest plant height from week 1 to 7. However, on weeks 1, 2, 4, 5, and 6, there were significant differences among treatments regardless of the soil pH condition. On the other hand, it was found that the highest plant height on week 7 was consistently observed in T_3 (e.g. Acidic- 66.00 cm & Neutral- 74.00 cm) for both soil conditions. Regardless of the soil condition, the application of 0- 60- 60 kg/ha N-P_2O_5-K_2O (T_3) increased the plant height of sweet basil. Overall, good performance of sweet basil was observed in neutral soil (Fig. 3). The highest plant height was obtained in T_3 with no N. This is significantly different from T_5 applied with 180 kg/ha N. This shows that higher doses of N and K applied to sweet basil could decrease plant height.

b. Number of Primary Branches

Figure 2b shows the primary branches of sweet basil at harvest as affected by different nitrogen and potassium doses under different pH conditions. The highest number of primary branches was observed in T_6 (18) under neutral soil condition (Fig. 3). Subsequently, the lowest primary branches were observed in T_1 (control). This shows that high N and K doses could decrease primary branches of sweet basil (T_1, T_4, T_5 and T_8). Sweet basil produced an abundant number of primary branches mainly in neutral soil. Similarly, as reported by Nurzyńska-Wierdak (2012), the number of basil plant branching was on average 12.5 pieces per plant and significantly depended on the cultivar and dose of applied nitrogen. Moreover, the basil plants had different numbers of branchings (5.2–45.5 pieces per plant) (Kandil et al 2009; Said Al Ahl & Mahmoud 2010; Nurzyńska-Wierdak & Borowski 2011) which was related to their height and habit. However, that number decreased as an effect of salt stress (Said-Al Ahl & Mahmoud 2010) which proves the sensitivity of basil to excessive concentration of nutrients in the substratum reported at medium and the highest nitrogen doses.

c. Root Length

Roots are useful in the uptake of nutrients for plants. They absorb water and nutrients from the soil and translocate them to plant tops (Merrill et al 1996; Sainju et al 2005 & Stone et al 2001) through mass flow, diffusion, or root interception. As much as 7-43% of the total aboveground and belowground plant biomass can be contributed by roots (Kuo et al 1997). Figure 2c shows that the highest root length was observed in T_1 (control) with the value 27.33 cm (neutral). Root length of sweet basil increased under neutral soil condition even if there were no fertilizers applied. The longer the roots, the greater their capacity to absorb nutrients in the soil. On the other hand, the results revealed that the macronutrient content in water, especially

N, was relatively high (610-630 µg/mL) (Moreno 2018). This can influence the root length of sweet basil especially in T_1 (control). However, the shortest root length was observed in T_5 and T_8, both with the highest rates of N and K applied. This could be due to salt injury from application of high doses of fertilizers. High soil salt levels can prevent roots from absorbing adequate water so plants and trees grow poorly (Hanson 2013). Comfort et al (1988) found that high rates of application of N reduced root growth and depth of rooting in wheat. Moreover, as the level of K increased, the root length decreased (Fig. 2c).

Effects of Nitrogen and Potassium on the Yield of Sweet Basil

a. Fresh and Dry Leaf Weights

Figure 5a shows the fresh leaf weight of sweet basil. It was found that regardless of soil condition, T_3 (0-60-60 kg/ha N-P_2O_5-K_2O) had the highest amount of fresh leaf weight (118 g/pot). It was also observed in T_6 (60-60-0 kg/ha N-P_2O_5-K_2O) with 80.06 g/pot. Potassium fertilization also affects the growth, as well as basil yield quantity and quality (Rao et al 2007; Nguyen et al 2010). Kandil et al (2009) obtained the highest fresh basil herb yield and the highest basil essential oil yield when the highest NPK rates were applied. However, the results show that with increasing N application, fresh leaf weight decreased especially in T_4 (120- 60- 60 kg/ha N-P_2O_5-K_2O) with 33.37 g/pot, and T_5 (180- 60- 60 kg K_2O/ha N-P_2O_5-K_2O) with 24.53 g/pot.

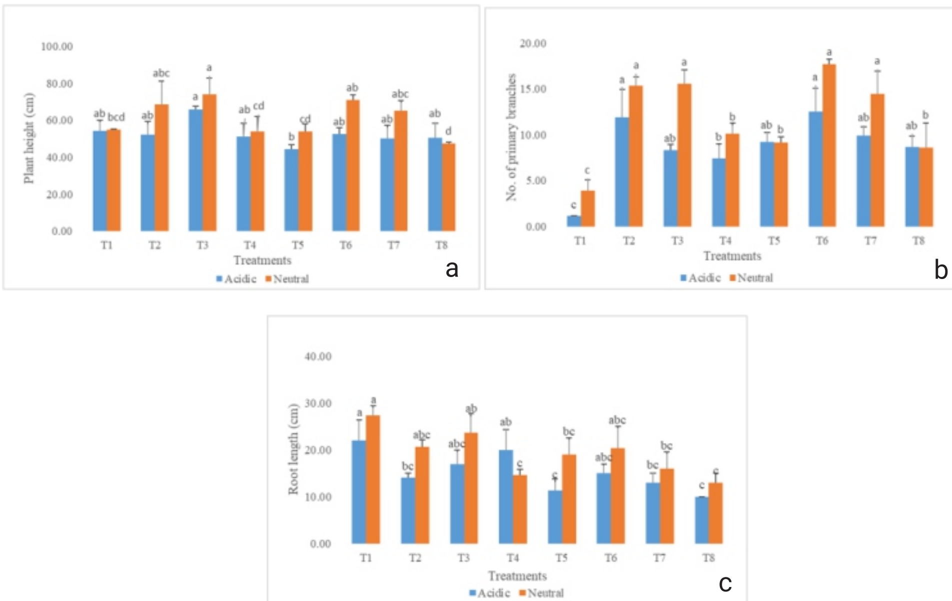
Figure 5b shows the dry leaf weight of sweet basil. T_3 had the highest dry matter weight (52.77 g/pot) among all treatments under neutral soil condition. Increasing amounts of N applied (e.g. 120 and 180 kg N/ha) could lessen sweet basil's leaf weight and affect its growth. This was due to nitrogen toxicity and salt injury upon addition of too much fertilizer. Plants tend to experience stunted growth, severe yellowing of the leaves, wilting, and death in severe cases. On the other hand, potassium accumulation, reaching a few percent of dry matter, takes place mainly in the leaves. The level of this nutrient is usually higher than that of the other macroelements (Biesiada & KuĞ 2010; Dzida 2010; Dzida & Jarosz 2010). Increasing application of K can decrease leaf weight.

b. Fresh and Dry Herbage Yield

Sweet basil herbage yield is shown in Figure 5c. Treatment 3 (0-60-60 kg/ha N-P_2O_5-K_2O/ha) had the highest amount of fresh herbage yield (216.77 g/pot) among all treatments including those planted in acidic soil. Sweet basil can obtain high amounts of herbage yield even with 0 N applied into the soil under neutral soil conditions. The same trend was observed in all treatments under the two soil conditions (Fig. 5d). The higher the amount of N and K applied, the lower the herbage yield.

Figure 5d shows the dry herbage yield of sweet basil under two soil types applied with different doses of nitrogen and potassium. The same trend was observed for fresh weight (Fig. 5c), T_3(71.50 g/pot) had the highest dry matter yield. Whether the nitrogen was limited/deficient, sweet basil could still acquire high amounts of dry herbage yield under neutral soil condition. In a three-year experiment

(1973–1975) carried out in Poznan, Poland, increasing N-doses (0–200 kg/ha) increased the total dry herb yield significantly. At 200 kg/ha nitrogen applied increases the yield by 44% with higher phosphorus and potassium doses, 80 and 160 kg/ha, respectively (Czabajski 1978).



Legend:

- T_1 – Control (No fertilizer)
- T_2 – 60-60-60 kg/ha N-P_2O_5-K_2O
- T_3 – 0-60-60 kg/ha N-P_2O_5-K_2O
- T_4 – 120-60-60 kg/ha N-P_2O_5-K_2O
- T_5 – 180-60-60 kg/ha N-P_2O_5-K_2O
- T_6 – 60-60-0 kg/ha N-P_2O_5-K_2O
- T_7 – 60-60-120 kg/ha N-P_2O_5-K_2O
- T_8 – 60-60-180 kg/ha N-P_2O_5-K_2O

Figure 2. Growth parameters of sweet basil: (a) plant height (cm); (b) number of primary branches; (c) root length (cm) at harvest as affected by different nitrogen and potassium doses under neutral and acidic soil condition

c. Fresh and Dry Root Weight

Roots are very important in plant growth. All processes in the soil have direct contact with plant roots most importantly in plant uptake of water and nutrients (e.g. mass flow, diffusion, and root interception). Root morphology is influenced by the amount of N fertilizer applied (Eghball et al 1993). The bigger the roots, the higher is the capacity to absorb nutrients available for plant use. Figures 13 and 14 show the fresh and dry root weight of sweet basil. T_3 (0-60-60 kg N-P_2O_5-K_2O/ha) under neutral soil condition had the highest fresh root weight (9 g/pot). A similar trend for fresh and dry weight (Figs. 5e and 5f) was observed under neutral soil condition. Increasing application of N and K could decrease fresh and dry root weight. This was observed in Treatments 4 and 5 in both soil conditions. Small and undesirable appearance of roots were observed. However, good rooting system was consistently observed under neutral soil (Fig. 4). Nitrogen improves production of lateral roots and root hairs, as well as increasing rooting depth and root length density deep in the profile (Hansson & Andren 1987). Nitrogen deficiency also reduces branching and root hairs in cereals and legumes (Baligar et al 1998). On the other hand, K has been shown to promote the root growth of some vegetable crops (Zhao et al 1991).

Effects of Nitrogen and Potassium on the Plant Quality Sweet Basil

a. Chlorophyll (SPAD)

Chlorophyll is a pigment or a chemical compound that absorbs and reflects specific wavelengths of light. Figure 6a shows that T_2 (RR 60-60-60 kg/ha N-P_2O_5-K_20) under neutral soil had the highest amount of chlorophyll (e.g. 44.79) among all treatments while the lowest was observed in the control (acidic soil condition). Optimum application of N for sweet basil could increase chlorophyll content (SPAD) under neutral soil condition. Increasing levels of N and K had no significant effect among treatments. This only result to optimum level of N which increased the chlorophyll present in the leaves. This supports the direct relationship between chlorophyll and N content. Nitrogen is a major component of chlorophyll, the compound by which plants use sunlight energy to produce sugars from water and carbon dioxide (e.g. photosynthesis). Optimum application of fertilizers, especially N, can increase chlorophyll content. Inadequate N application leads to a decrease in leaf area (Fernandez et al 1996), chlorophyll content, leaf photosynthesis, biomass production (Zhao & Oosterhuis 2000), and the loss of yields and qualities. At higher doses, a decreasing value of chlorophyll was observed, similar to what occurred in the study (Masumo et al 2013).

b. Chlorophyll A and B

The primary pigment of photosynthesis is chlorophyll A. Chlorophyll A absorbs light from the orange-red and violet-blue areas of the electromagnetic spectrum. Figure 6b shows that T_2 (acidic soil- 6.36 nmol/mL), T_4 (acidic soil- 5.96 nmol/mL), and T_6 (neutral soil- 6.48 nmol/mL) obtained the highest chlorophyll a value. Optimum addition of N and 0 kg K_2O can increase chlorophyll a. Further, chlorophyll A values also increased in treatments with increasing N and K_2O levels added to the soil. Treatments 2 and 4 under acidic soil condition could increase chlorophyll A while under neutral soil, T_6significantly increased chlorophyll a.

Chlorophyll B helps in photosynthesis by absorbing light energy. It is more soluble than chlorophyll A in polar solvents because of its carbonyl group. Its color is green, and it primarily absorbs blue light. Figure 6c shows that T_2 (60- 60- 60 kg/ha N-P_2O_5-K_2O) (12.54 nmol/mL) had the highest amount of chlorophyll B under acidic soil condition. However, in neutral soil, highest chlorophyll B was observed in T_6 (60- 60- 0 kg/ha N-P_2O_5-K_2O) (12.75 nmol/mL). Optimum amounts of N under acidic soil could increase chlorophyll B while 0 K_2O could increase chlorophyll B under neutral soil condition. There is a positive correlation between increasing doses of N and chloroplastidic pigments, with higher coefficients of chlorophyll b and carotenoids (Politycka & Golcz 2004). Both chlorophyll A and B were found to be the highest in T_2 (60-60-60 kg/ha N-P_2O_5-K_2O) under acidic soil condition and T_6 (60-60-0 kg/ha N-P_2O_5-K_2O) under neutral soil condition. This signifies the important rates of optimum levels of NPK in the chlorophyll production of sweet basil.

a

b

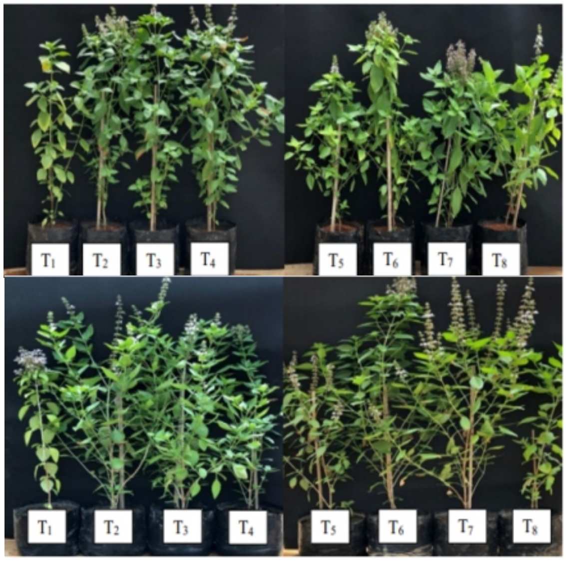
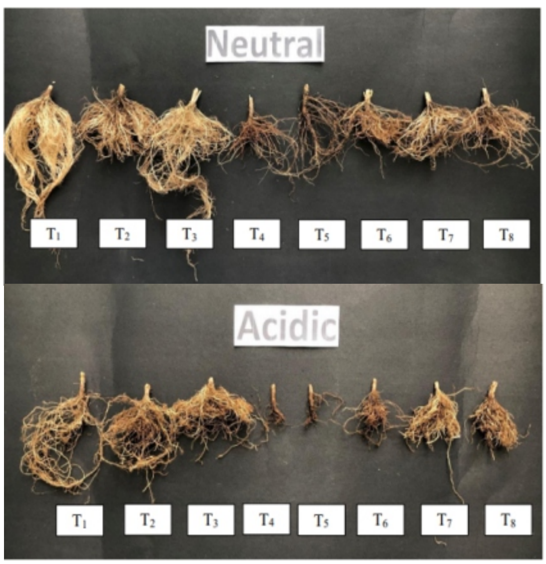


Figure 3. Sweet basil at harvest (7 WAT) as affected by different nitrogen and potassium doses under neutral (a) and acidic (b) soil condition

a

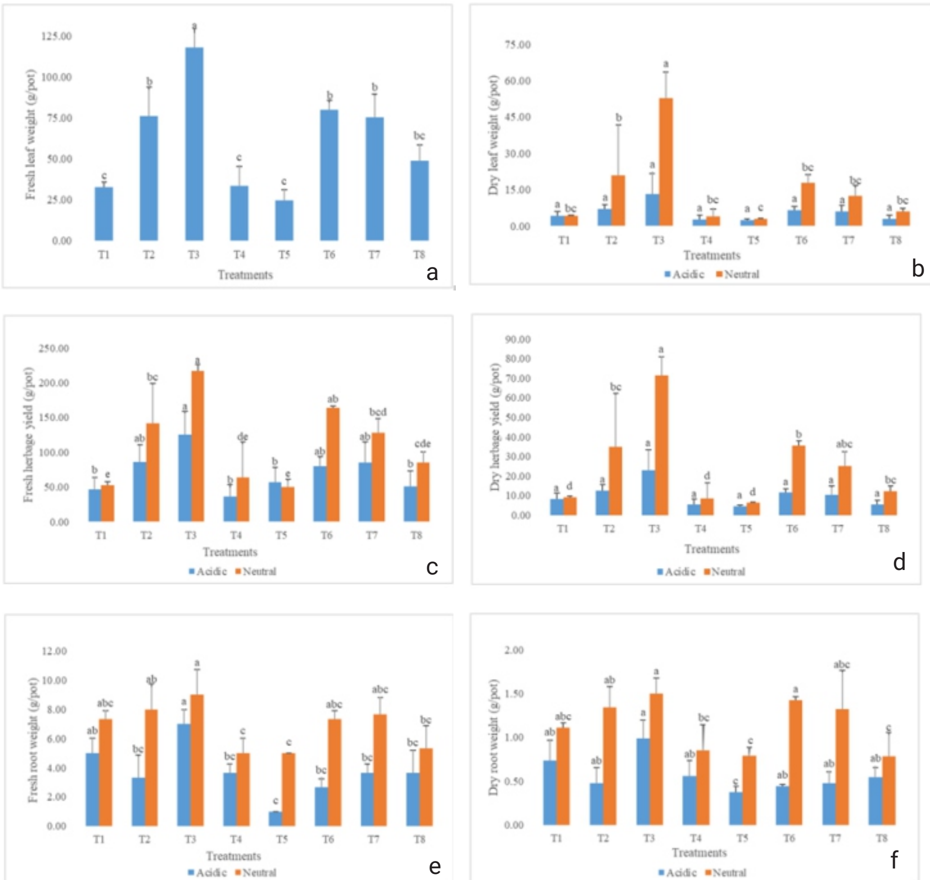
b



Legend:

T_1 – Control (No fertilizer)
T_2 – 60- 60- 60 kg/ha N-P_2O_5-K_2O
T_3 – 0- 60- 60 kg/ha N-P_2O_5-K_2O
T_4 – 120- 60- 60 kg/ha N-P_2O_5-K_2O
T_5 – 180- 60- 60 kg/ha N-P_2O_5-K_2O
T_6 – 60- 60- 0 kg/ha N-P_2O_5-K_2O
T_7 – 60- 60- 120 kg/ha N-P_2O_5-K_2O
T_8 – 60- 60- 180 kg/ha N-P_2O_5-K_2O

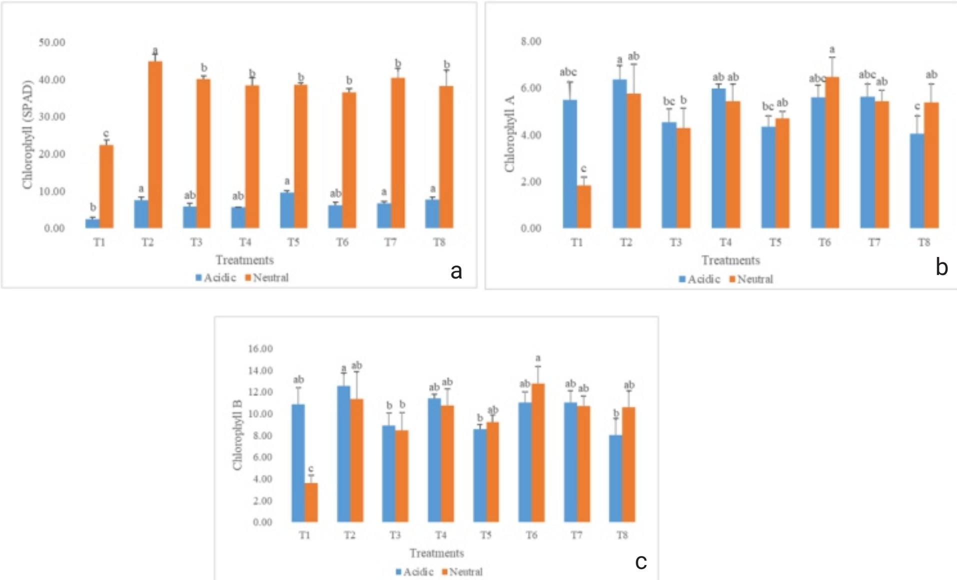
Figure 4. Root length of sweet basil as affected by different nitrogen and potassium doses under neutral (a) and acidic (b) soil condition



Legend:

T_1 – Control (No fertilizer)
T_2 – 60- 60- 60 kg/ha N-P_2O_5-K_2O
T_3 – 0- 60- 60 kg/ha N-P_2O_5-K_2O
T_4 – 120- 60- 60 kg/ha N-P_2O_5-K_2O
T_5 – 180- 60- 60 kg/ha N-P_2O_5-K_2O
T_6 – 60- 60- 0 kg/ha N-P_2O_5-K_2O
T_7 – 60- 60- 120 kg/ha N-P_2O_5-K_2O
T_8 – 60- 60- 180 kg/ha N-P_2O_5-K_2O

Figure 5. Yield parameters of sweet basil: (a) fresh leaf weight (g/pot); (b) dry leaf weight/plant (g/pot); (c) fresh herbage yield at harvest (g/pot); (d) dry matter at harvest (g/pot); (e) fresh root weight (g/pot); (f) dry root weight (g/pot) at harvest as affected by different nitrogen and potassium doses under neutral and acidic soil condition



Legend:

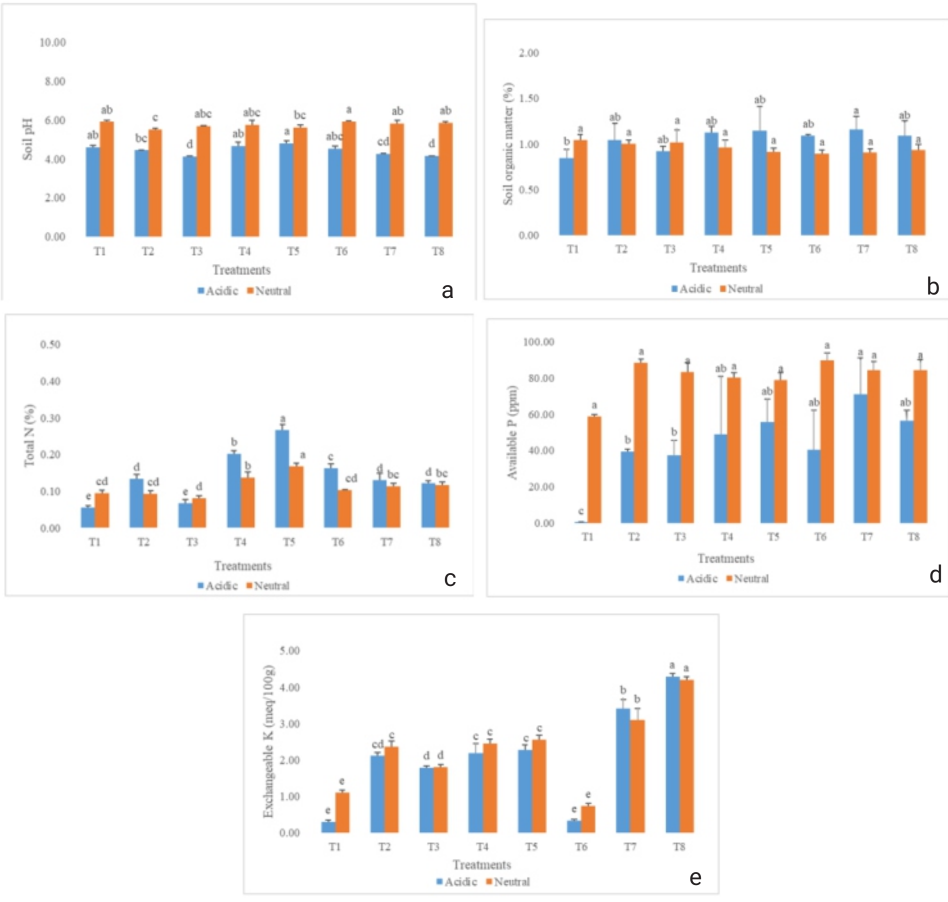
T_1 – Control (No fertilizer)
T_2 – 60- 60- 60 kg/ha N-P_2O_5-K_2O
T_3 – 0- 60- 60 kg/ha N-P_2O_5-K_2O
T_4 – 120- 60- 60 kg/ha N-P_2O_5-K_2O
T_5 – 180- 60- 60 kg/ha N-P_2O_5-K_2O
T_6 – 60- 60- 0 kg/ha N-P_2O_5-K_2O
T_7 – 60- 60- 120 kg/ha N-P_2O_5-K_2O
T_8 – 60- 60- 180 kg/ha N-P_2O_5-K_2O

Figure 6. Quality of sweet basil: (a) chlorophyll contents (SPAD); (b) chlorophyll A; (c) chlorophyll B contents at harvest as affected by different nitrogen and potassium doses under neutral and acidic soil condition

Effects of Nitrogen and Potassium on Soil Chemical Properties

a. Soil pH

Soil pH is defined as the measure of the concentration of hydrogen ions in the soil solution (Gazey 2016). In addition, it is an indicator of the relative acidity and alkalinity of the soil and is considered as the control of many chemical and biological processes that affect plant nutrient availability. Figure 7a shows the results of soil pH as affected by different nitrogen and potassium doses under neutral and acidic soil conditions. High soil pH values were observed in T_6 (60-60-0 kg/ha N-P_2O_5-K_2O) and T_1 (Control) but, these were not significantly different from T_7 and T_8 in neutral soil. In comparison with its initial soil pH (e.g. 6.64), pH values were greatly affected upon the addition of nitrogen and potassium fertilizers. The soil pH values in all the treatments, ranging from 5.5 to 6.5, were considered as good for crop production. In contrast, the initial soil pH value for acidic soil was 5.22. Upon the addition of different levels of nitrogen and potassium fertilizers, lower soil pH values were consistently noticed under acidic soil condition (e.g. 4.10). The addition of nitrogen and potassium fertilizers can lower soil pH especially at its highest doses (e.g. T_4 & T_5). At some point, low soil pH can make Fe and Al abundant in soil which can cause plant death in severe cases.



Legend:

T_1 – Control (No fertilizer)	T_5 – 180-60-60 kg/ha N-P_2O_5-K_2O
T_2 – 60-60-60 kg/ha N-P_2O_5-K_2O	T_6 – 60-60-0 kg/ha N-P_2O_5-K_2O
T_3 – 0-60-60 kg/ha N-P_2O_5-K_2O	T_7 – 60-60-120 kg/ha N-P_2O_5-K_2O
T_4 – 120-60-60 kg/ha N-P_2O_5-K_2O	T_8 – 60-60-180 kg/ha N-P_2O_5-K_2O

Figure 7. Soil chemical properties: (a) soil pH; (b) soil organic matter (%); (c) total N (%)(d) available P (ppm); (e) exchangeable K (meq/100g) at harvest as affected by different nitrogen and potassium doses under neutral and acidic soil condition

Table 2. Initial chemical properties of the soil

PROPERTY	SAMPLES	
	ACIDIC	NEUTRAL
pH (1:2.5 soil to H_2O)	5.22	6.64
Soil Organic Matter (%)	1.06	0.80
Total N (%)	0.09	0.09
Available P (ppm)	0.15	60.41
Exchangeable K (meq/100g)	0.31	1.18

b. Soil Organic Matter

Soil organic matter provides most of the cation exchange capacity (CEC) and water holding capacity of surface soils. Figure 7b shows the soil organic matter in both acidic and neutral soil as affected by the addition of nitrogen and potassium fertilizers. Initial soil organic matter were 1.06 % and 0.80 % inacidic and neutral soil, respectively. Under acidic and neutral soil, the highest OM was obtained in T_7 (1.16 % & 0.90 %). The lowest was obtained in the control (0.85) under acidic soil. Moreover, the addition of different levels of N and K was not signifcantly different among did not significantly affect the treatments (Fig. 7b). According to Landon 1991, both results were categorized as low organic matter. Even after the addition of nitrogen and potassium, the OM content of the soil remained low, although the levels increased.

c. Total Nitrogen

Nitrogen is one of the essential elements acquired by plants in ionic form of NO_3^- and NH_4^+ (Brady 1990). Total N is deficient mostly in the tropics since it undergoes various losses such as leaching and volatilization (Krofranek et al 2007). Initial total N for both soil conditions was 0.09 % (Table 1). Highest total nitrogen was observed in T_5 (180-60-60 kg/ha N- P_2O_5-K_2O) under acidic soil as shown in Figure 7c. T_5 had the highest amount of N added into the soil. According to Landon 1991, the value ranges from very low N to medium amounts of N. Total N was not significantly influenced by the different levels of N and K added into the soil. It was reduced by 0.03 % or 0.04 %. Total N amount in the treated pots was still considered medium (0.27 %) (Landon 1991) even if N was applied immensely in those pots (e.g. T_5).

d. Available Phosphorus

Phosphorus is one of the least available nutrients to plants and is the most limiting factor for plant growth (Hinsinger 2001). Figure 7d shows the available P in two soil types with the addition of different levels of N and K_2O. Table 1 shows that the initial available P were 0.15 ppm and 60.41 ppm in acidic and neutral soil, respectively.

The results show that on neutral soil, the addition of different levels of fertilizers can increase available P but this was not significantly different to the other treatments. However, on acidic soil, highest available P was noticed on T_7 (60- 60 - 120 kg/ha N-P_2O_5-K_2O). High available P for sweet basil was observed under neutral soil as P was available at near neutral soil pH. This implies that sweet basil plants need only optimum amounts of P for plant growth as more phosphorus was found in the soil. Increasing amounts of N and K resulted to surplus amount of P in the soil. However, on neutral soil, very high amounts of P were noticed compared to acidic soil. Acidic soil tends to have low P because it has been fixed with iron and aluminum in the soil.

d. Exchangeable K (meq/100g)

Potassium (K) is a major key element essential in the synthesis and translocation of carbohydrates from the top of the plant to the roots (Byju & Nedunchezhiyan 2004).

Highest exchangeable K were observed in T_8 (60- 60- 180 kg/ha N-P_2O_5-K_2O) under the two soil types (Figure 7e). Initial soil exchangeable K were 0.81 meq/100g and 1.18 meq/100g in acidic and neutral soil, respectively (Table 1). According to Landon 1991, values obtained were very high. The same trend was observed from T_1 to T_8. The higher the amount of K fertilizer added into the soil, the higher was the amount of exchangeable K. However, increasing levels of nitrogen added into the soil increased the amount of exchangeable K in the soil for both soil types. Lowest exchangeable K was observed both in the control and T_6 (60-60-0 kg/ha N-P_2O_5-K_2O) under acidic soil condition. Sweet basil tends to absorb potassium in smaller amounts due to high amounts of exchangeable K found in the soil. Growing sweet basil only needs 60 kg/ha K_2O/ ha. T_7 (60-60-120 kg/ha N-P_2O_5-K_2O and T_8 (60-60-180 kg/ha N-P_2O_5-K_2O) had a surplus supply of K for sweet basil. Moreover, exchangeable K was significantly influenced by the application of different levels of N and K. Optimum application of K is enough to have a good harvest of sweet basil.

Effects of Nitrogen and Potassium on Plant Tissue of Sweet Basil

a. Total N (%)

Nitrogen is an important yield enhancing primary nutrient and is necessary for building amino acids, structural elements of proteins as well as pyrimidine and purine bases, nucleotides, and nucleic acids. Basil has substantial nutritional needs. Nitrogen favorably affects plant growth and yield (Sifola & Barbieri 2006; Rao et al 2007; Zheljazkov et al 2008; Daneshian et al 2009).

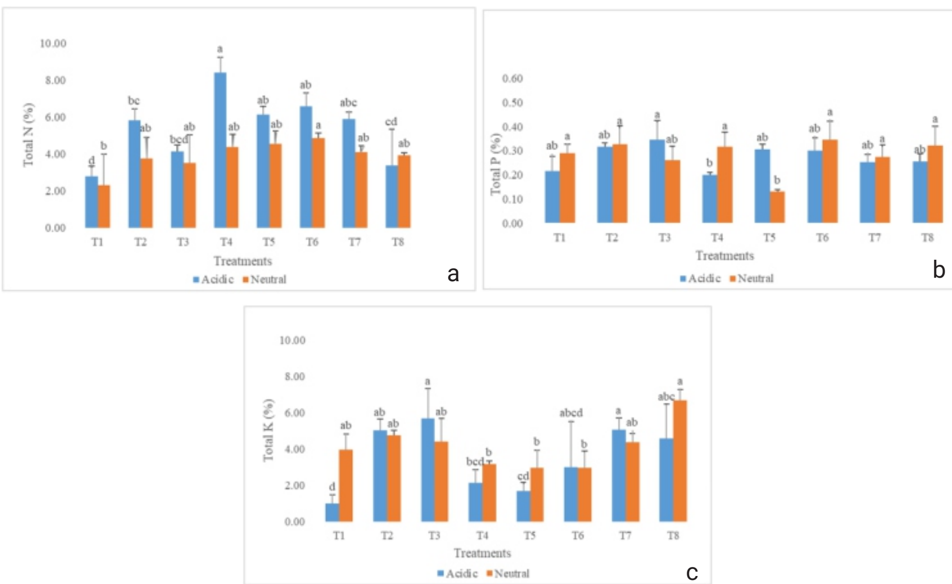
Figure 8a shows that very high amounts of total N in tissue of sweet basil was observed in all treatment plants. However, the highest amount of total N was noticed in T_4 (120- 60- 60 kg/ha N-P_2O_5-K_2O) under acidic soil. On the other hand, increasing amounts of N added into the neutral soil resulted to more or less the same values with high amounts of N and K treatments. However, on acidic soil, increasing amounts of N yielded increase in total N but this eventually decreased in T_8 (60-60-180 kg/ha 60 kg N-P_2O_5-K_2O). Meanwhile, addition of increasing levels of K_2O resulted to decrease in total N in T_8 (60-60-180 kg/ha 60 kg N-P_2O_5-K_2O). This implies that sweet basil plants required high amounts of N but this should not exceed 120 to 180 kg N/ha as plants tend to have stunted growth and yellowing of leaves. Treatment 4 under acidic soil condition increased amounts of Total N (8.40

%). However, high amounts of N applied can cause salt stress and toxicity to plants especially plant roots. Money, time, and effort would be wasted upon application of high amounts of N.

b. Total P (%)

Phosphorus (P) is considered the most limiting nutrient next to nitrogen (N) for the growth and metabolism of plants. It plays an important key role in the cellular energy transfer and storage, respiration, photosynthesis (Glass et al 1980; Usuda & Shimogawara 1993), and as a structural component of nucleic acid and membranes (Schachtman et al 1998; Ragothama 1999).

Highest amount of total P was observed on T_3(acidic soil) and T_6 (neutral soil)as shown in Figure 8b. Sweet basil tissue had high amounts of Total P (%) acquired if T_3 (0.35 %) and T_6 (0.35%) were used wherein both have 0 N and K applied. However, increasing amounts of N fertilizers applied yielded low amounts of P T_4- 0.20 % (acidic) & T_5- 0.13 % (neutral), respectively. Sweet basil planted in neutral soil had the highest values of P as compared to acidic ones. It tends to absorb small amounts of P if it was planted on acidic soil. Phosphorus tends to be fixed in the soil and not available for plant use.



Legend:

T_1 – Control (No fertilizer)
T_2 – 60- 60- 60 kg/ha N-P_2O_5-K_2O
T_3 – 0- 60- 60 kg/ha N-P_2O_5-K_2O
T_4 – 120- 60- 60 kg/ha N-P_2O_5-K_2O
T_5 – 180- 60- 60 kg/ha N-P_2O_5-K_2O
T_6 – 60- 60- 0 kg/ha N-P_2O_5-K_2O
T_7 – 60- 60- 120 kg/ha N-P_2O_5-K_2O
T_8 – 60- 60- 180 kg/ha N-P_2O_5-K_2O

Figure 8. Total N (a), Total P (b) and Total K (c) at harvest as affected by different nitrogen and potassium doses under neutral and acidic soil condition

c. Total K (%)

Potassium does not form organic compounds in plants and occurs exclusively in ionic form. Thus, it is one of the most dynamic (movable) elements in a plant. The share of potassium ions in regulating plant water management, transpiration process and other important metabolic processes is highly specific. Under neutral soil condition, highest value of total K was observed in T_8 (60-60-180 kg/ha N-P_2O_5-K_2O). Total Potassium (%) decreased as the level of nitrogen increased, as shown in Figure 8c. However, as the level of potassium applied in the soil increased the total potassium also increased. High Total K (%) was observed (6.68 %) in neutral soil. This implies that increasing amounts of K could increase Total K especially under neutral soil condition.

CONCLUSIONS

Based on the results obtained, this study concludes that in terms of plant growth, the highest plant height was observed under neutral soil (T_3- 74 cm). Moreover, the highest number of primary branches was observed in T_6 under neutral soil condition. In contrast, lowest number of primary branches was observed in T_1 under acidic soil condition. The highest root length was observed under neutral soil (T_1- 27.33 cm). The yield of sweet basil was significantly influenced by addition of N and K doses. The highest fresh weight of leaf was observed in T_3 (118 g/pot) while the lowest was obtained in T_5 (24.53 g/pot). Likewise, both highest fresh (216.77 g/pot) and dry (71.50 g/pot) herbage yield was obtained in T_3 under neutral soil condition. A similar trend was observed in fresh and dry root weight of sweet basil. The highest fresh root weight was obtained in T_3(9 g/pot) while the lowest was obtained in T_5 (1 g/pot). The highest SPAD chlorophyll was obtained in T_2 (Neutral- 44.79). Similarly, high levels of chlorophyll a was obtained in T_2 (acidic soil- 6.36 nmol/ml), T_4 (acidic soil- 5.96 nmol/ml), and T_6 (neutral soil- 6.48 nmol/ml), while the highest chlorophyll b was observed in T_2 (Acidic- 12.54 nmol/ml). In terms of plant tissue, highest % N, % P, and % K in the leaf tissue were recorded in T_4 (%N content of 8.40), T_3 and T_6 (% P of 0.35), and T_8 (% K of 6.67).

The optimum combination of N and K doses that was highly favorable under both neutral and acidic condition was T_3 (0-60-60 kg/ha N-P_2O_5-K_20), indicating that sweet basil needs small amounts of N for its growth and yield.

The chemical properties of neutral and acidic soil were significantly affected by N and K combinations. The following treatments resulted in the highest soil chemical properties: T_6 (soil pH of 5.91) and T_7 (soil OM of 1.16% and 0.90%). The highest total N was observed in T_5 (Acidic- 0.27 %) and highest exchangeable K in T_8 (Acidic- 4.29 meq/100g & Neutral- 4.19 meq/100g).

RECOMMENDATIONS

For further improvement, field experiments should be conducted to verify the results obtained under pot experiment following the treatment combinations used in the study. The optimum combination of N and K doses that was highly favorable under both neutral and acidic condition was T_3(0-60-60 kg/ha N-P_2O_5-K_20), indicating that sweet basil needs small amounts of N for its growth and yield. Aside from varying the amounts of N and K, it is suggested that the use of micronutrient biofortification be explored in sweet basil production

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