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Effect of Different Nutrient Sources and Moisture Stress on Nutrient Uptake and Dry Matter Accumulation of Indian Spinach (*Basella alba* L.)

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Abstract

Most tropical soils are deficient in major plant nutrients. This is exacerbated by moisture stress which makes the meagre nutrients unavailable for plant uptake. This study was conducted at the screen house of Federal University of Technology Minna to determine the effect of nutrient sources and moisture stress on the performance of Indian spinach**.** The treatments were 4 nutrient sources (control, NPK 20-10-10, poultry manure, sapropel) and 4 moisture stress levels (daily, 2, 4, 6 days watering intervals) arranged in Completely Randomized Design. Results revealed that poultry manure significantly increased the dry matter of Indian spinach by 87% over the control while sapropel did not. Application of poultry manure significantly increased phosphorus uptake by 244% over the control which was similar to NPK fertilizer while sapropel increased the uptake by 85%. Plants fertilized with NPK had significantly ($p<0.05$) highest nitrogen, potassium, calcium and magnesium uptake followed by poultry manure. The least was obtained in the control plants which was statistically similar to the sapropel treated plants. Significantly highest dry matter was obtained in daily watered plants which were similar to 2 days watering interval. Similar trend was observed for all the nutrient uptake. Moisture stress imposed from 4 days watering interval significantly reduced the dry matter, N, P, K and Mg uptake in the plants. This result suggests that poultry manure will be a better alternative to chemical fertilizer in the production of Indian spinach than sapropel. Furthermore, watering at 2 days interval is adequate for the crop's optimum performance.

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Introduction

Indian spinach (*Basella alba* L.) *is* a vigorous perennial climbing plant cultivated as a leafy vegetable and ornamental in tropical, subtropical and occasionally extending into temperate regions as an annual Vélez-Gavilán (2018). Common names include Malabar spinach and Ceylon spinach. It is called 'Amunututu' in Yoruba, 'Alayyahu mai ruwa' in Hausa and 'Ngbolodi' among the Igbo speaking people in Nigeria. The young stems and tips of the vegetable are used in cooking and making salad. The leaves and stem are rich in vitamin A and C, potassium, manganese, calcium, magnesium, copper, iron and numerous B-complex nutrients such as folate, pyridoxine and riboflavin (Grubben and Denton, 2004). Indian spinach has been reported for use in the treatment of numerous sicknesses like loose bowels, iron deficiency, ulcer, fever, hormonal imbalance, constipation, inflammation, wound and neutralize poison due to its restorative properties (Kumar *et al*., 2013). They are rich in various industrially important chemicals such as acacetin, anthraquinone, basellasaponins A, B, C and D, betacyanin, ferulic acid (Kumar *et al*., 2013).

Plate 1: Indian Spinach (*Basella alba*) plant

Plant growth and productivity is a function of environmental factors among which the most important are soil nutrient and moisture. Almost every process in the plant system is affected by water. It plays significant role in homeostasis maintenance and cell composition formation. Lisar *et al*. (2012) reported that 80-90% of the biomass of non-woody plants comprise of water and it is the central molecule in all physiological processes of plants. It is the major medium for transporting metabolites and nutrients. Water stress is primarily caused by the water deficit i.e. drought or high soil salinity. Plants experience water stress either when the water supply to their roots becomes limiting or when the transpiration rate becomes intense. Water stress in plants reduces the plant-cell's water potential and turgor, which elevate the solutes' concentrations in the cytosol and extracellular matrices. As a result, cell enlargement decreases leading to growth inhibition and reproductive failure. This is followed by accumulation of abscisic acid (ABA) and compatible osmolytes like proline, which cause wilting (Lisar *et al*., 2012). Furthermore, water deficit reduces the availability and uptake of nutrients by plant roots thereby limiting crop growth and development. Climate change has negatively impacted on the availability of water; there is increasing scarcity of irrigation water (Zhang *et al*., 2014). It is therefore important to practice climate smart agriculture in which just the adequate amount of water is made available to the plant. Adoption of a suitable irrigation water management practice is necessary to improve crop productivity and reduce cost of production.

A constant and sustained supply of plant nutrients is important for the enhancement of global crop production in terms of quality and quantity to meet the food demand of the growing population. Successful commercial vegetable production cannot be achieved without fertilizer application in the tropics as tropical soils are deficient in major nutrient element (Kostov, 2016). Application of inorganic or organic fertilizers are the major ways through which plant nutrient is been supplied to maintain productivity but the use of inorganic fertilizers is not sustainable due to its deleterious effects on the environment and human health. It is therefore important to test other alternative organic sources of plant nutrients which are more environmentally friendly. Use of animal manure has been reported to improve the productivity of crop among which poultry manure has been reported to be effective by many researchers. However, considering the bulkiness and messy nature of animal dung, it is important to test other organic alternative. Sapropels are subaqueous layers formed at the bottom of nutrient rich water under anaerobic condition (Ismail-Meyer *et al*., 2018). It is a clean and ecologically friendly natural material obtained from remains of plankton, water plants and other water dwelling organism used as biofertilizers and in soil conditioning (Marunga *et al*., 2020). This study therefore aimed at determining the effect of water stress and suitability of poultry manure and sapropel as replacement for inorganic fertilizer for Indian spinach production.

Materials and Methods

The experiment was conducted between August and October, 2019 at the screen house of Federal University of Technology, Minna, Nigeria. It was a 4 x 4 factorial experiment comprising 4 water stress levels (daily watering, 2, 4 and 6 days watering intervals) and 4 nutrient sources (control, NPK 20-10-10, poultry manure and sapropel biofertilizer). These were arranged in Completely Randomized Design (CRD) with four replicates. Four seeds were sown per pot filled with 3.5 kg of top soil at a depth of 5 cm. The seedlings were thinned to two stands per pot at two weeks after sowing. The water stress schedule was introduced at 3 weeks after sowing following the treatments. At each watering day, the soil was watered to field capacity with 40 cl of water per pot. NPK 20-10-10, sapropel and poultry manure were applied at the rate of 625 kg ha^{-1}, 1580 kg ha^{-1} and 3 ton ha^{-1} respectively according to the recommendations of Pujari (2017), Salami and Babajide (2015). The sapropel used (Emerald fertilizer sapropel) contained 7.91% N, 17.37 mg/kg phosphate and 7.76 mg/kg potassium.

The plants were harvested at nine weeks after sowing. The dry matter was obtained by oven drying the harvested plants at 70°C until constant weight was obtained. The total nitrogen present in the plant tissues was determined using micro Kjeldahl method as described by Okalebo (2002). The phosphorous available in the plant tissues was determined using the Bray 2 method as described by Okalebo (2002). Potassium, calcium and magnesium were extracted with ammonium acetate solution. Potassium was read using flame photometer while exchangeable magnesium and calcium were read with atomic absorption spectrometer Okalebo (2002). The uptake of the above nutrients were determined using the equation below:

$$\frac{\text{\% Nutrient in plant tissue} \times \text{dry matter}}{100}$$

(Sharma *et al.*, 2012)

All data collected were subjected to analysis of variance (ANOVA) using statistical analysis system (SAS).

Results

Effect of moisture stress on dry matter accumulation and nutrient uptake of Indian spinach

Dry matter accumulation in plants that received every day and 2 days watering intervals were similar (7788.57 and 7700 mg/kg soil respectively) and statistically higher than the plants that received 4 days and 6 days watering interval which had the least dry matter yield (6102.86 and 5862.86 mg/kg soil respectively) (Figure 1).

There was no significant difference between the N-uptake of Indian spinach that received every day, 2 days and 4 days watering interval (354.33, 366.95 and 286.18mg/kg soil respectively). The least N-uptake was observed at 6 days watering interval which was significantly lower (261.48mg/kg soil) than plants that received 2 days watering interval (Figure 2).

Phosphorus (P) uptake of the plants that received every day and 2 days watering intervals were similar (1.42 and 1.40 mg/kg soil respectively) and statistically higher than the plants that received 6 days watering interval which had the least P-uptake (1.00 mg/kg soil) (Figure 3).

There was no significant difference between the potassium (K) uptake of the plants that received every day and 2 days watering interval (3.94 and 4.08 mg/kg soil respectively). The least K-uptake was observed at 4 days and 6 days watering interval which were statistically similar (2.48 and 2.62 mg/kg soil respectively) (Figure 3).

There was no significant difference between the magnesium (Mg) uptake of plants that received every day, 2 days and 4 days watering interval (1.10 and 1.16 mg/kg soil respectively). The least Mg-uptake was observed at 6 days watering interval (0.71 mg/kg soil respectively) which was significantly lower than plants that received 2 days watering interval. Similar trend was observed for calcium (ca) uptake (Figure 3).

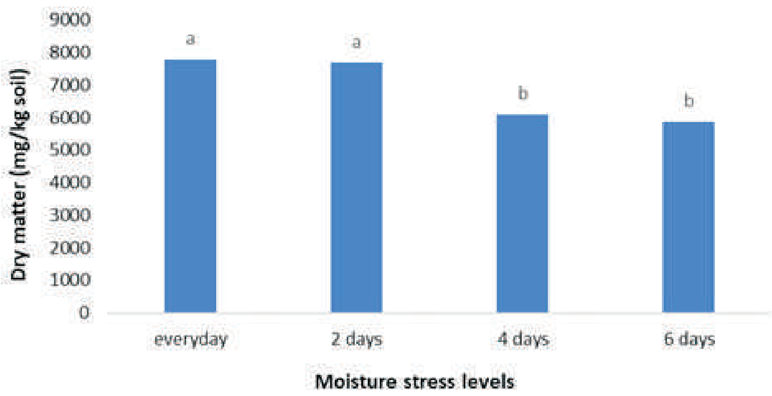

Figure 1: Dry matter of Indian spinach as affected by moisture stress

Means with the same letters are not significantly different at p≤0.5 using LSD

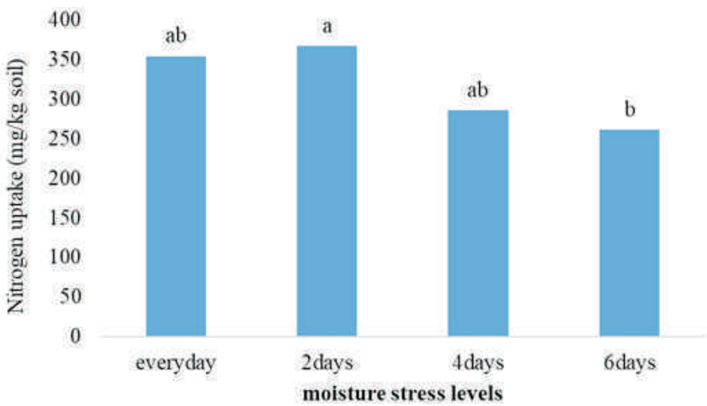

Figure 2: Nitrogen uptake of Indian spinach as affected by moisture stress.

Means with the same letters are not significantly different at p≤0.5 using LSD

Effect of nutrient sources on dry matter accumulation and nutrient uptake of Indian spinach

The plants treated with N.P.K fertilizer had the significantly highest dry matter yield (10365.71 mg/kg soil) followed by poultry manure (8188.57 mg/kg soil). The least dry matter yield was observed in control plants (4651.43 mg/kg soil) which were however statistically similar to sapropel treated plants (4902.86 mg/kg soil respectively) (Figure 4).

Plants treated with N.P.K fertilizer had significantly highest N-uptake (523.40 mg/kg soil), followed by plants that received poultry manure (343.37 mg/kg soil). The least N-uptake was observed in control plants 176.50 mg/kg soil similar to sapropel treated plants (225.67 mg/kg soil) (Figure 5).

The plants treated with poultry manure had significantly highest P-uptake (1.79 mg/kg soil) which was statistically similar to NPK fertilizer (1.63 mg/kg soil). This was followed by plants that received sapropel (0.96 mg/kg soil). The least P-uptake was observed in control plants (0.52 mg/kg soil) (Figure 6). Plants treated with N.P.K fertilizer had significantly highest K-uptake (4.89 mg/kg soil), followed by plants that received poultry manure (3.92 mg/kg soil). The least K-uptake was observed in control plants (1.87 mg/kg soil) statistically similar to sapropel treated plants (2.46 mg/kg soil) (Figure 6).

Plants treated with N.P.K fertilizer had significantly highest Mg-uptake (1.49 mg/kg soil), followed by poultry manure (0.90 mg/kg soil). The least Mg-uptake was observed in sapropel treated plants (0.59 mg/kg soil) similar to the control plants (Figure 6).

Plants treated with N.P.K fertilizer had significantly highest Ca-uptake (4.47 mg/kg soil), followed by poultry manure treated plants (3.14 mg/kg soil). The least Ca-uptake was observed in control plants (2.38 mg/kg soil). This was however statistically similar to the value obtained in sapropel treated plants (2.44 mg/kg soil) (Figure 6).

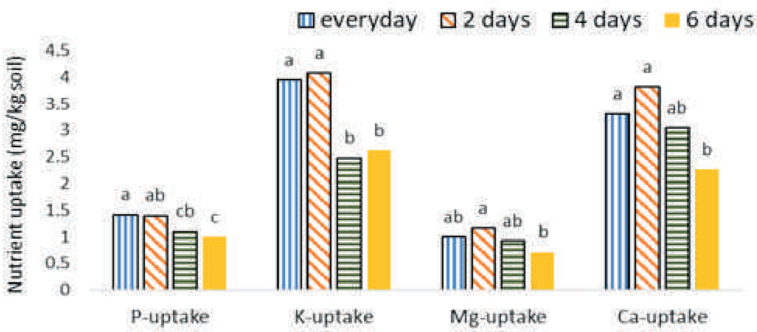

Figure 3. Nutrient uptake of Indian spinach as affected by moisture stress

Means with the same letters are not significantly different at p≤0.5 using LSD

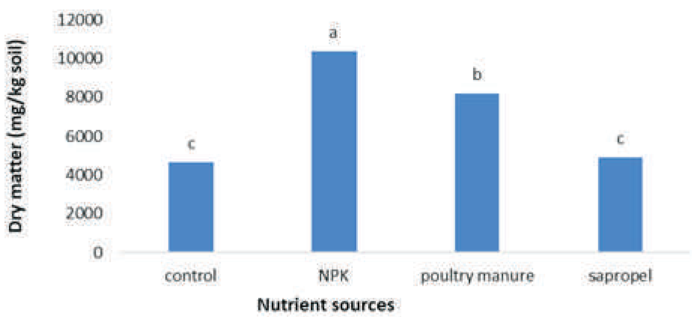

Figure 4: Dry matter of Indian spinach as affected by nutrient sources

Means with the same letters are not significantly different at p≤0.5 using LSD

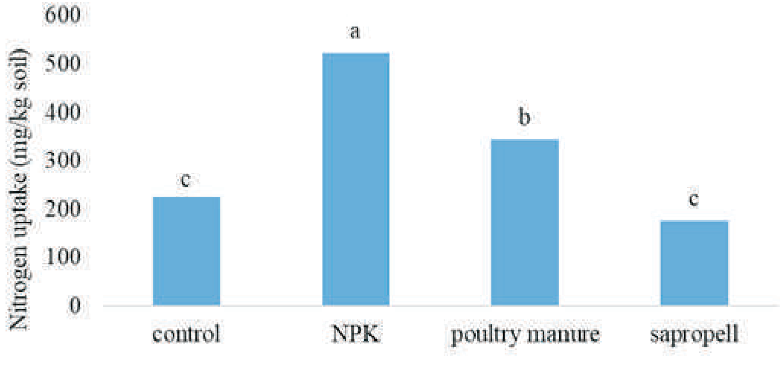

Figure 5: Nitrogen uptake of Indian spinach as affected by different nutrient sources.

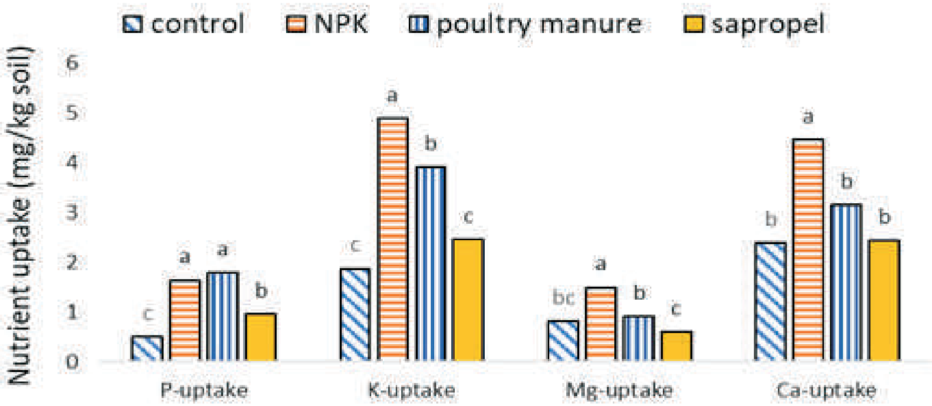

Figure 6. Nutrient uptake of Indian spinach as affected by nutrient sources

Discussion

The significant reduction observed in dry matter accumulation in 4 and 6 days watered plants compared to daily and 2 days watered plant suggests that moisture stress sets in after 2 days watering interval. Reduction in growth might have been responsible for reduction of dry matter recorded in the water stressed plants. Water is important for all physiological processes leading to growth in plants; among which photosynthesis is the most important for dry matter accumulation. Zhu *et al*. (2020) observed that moisture stress causes change in the photosynthetic properties of plants. When plants sense moisture deficit, they close their stomata to reduce loss of moisture through evapotranspiration. This is mainly controlled by chemical signals such as abscisic acid (ABA) production in dehydrating roots (Pirasteh-Anoshe, 2016). Stomata closure will in turn prevent inflow of carbon dioxide into the leaf mesophyll cell for carbon fixation in the dark reaction of photosynthesis. Water stress affects various physiological processes associated with growth, development and yield. Water deficit disturbs normal turgor pressure, and the loss of cell turgidity may stop cell enlargement leading to reduced plant growth (Srivalli *et al*., 2003).

The significantly higher nutrient uptake obtained in daily and 2 days watering compared to 4 and 6 days interval could be attributed to better water availability in the soil. Soil moisture is the most important factor that determine nutrient uptake in plants. Plants take up nutrients as ions; for nutrient uptake to occur in plants, the nutrient ion must be in position adjacent to the root. The nutrient ion is positioned through mass flow, diffusion or root interception. Mass flow and diffusion are responsible for the majority of nutrient uptake and are both dependent upon the presence of water in contact with the soil surface and the root. Smethurst (2004) similarly reported that the rate of uptake depends primarily on the concentration in the soil solution immediately adjacent to the root but the concentrations of nutrients at root surfaces depend strongly on soil water content.

The significantly higher dry matter accumulation and nutrient uptake observed in NPK and poultry manure treated than control plants confirms the importance of nutrient amendments in enhancing not only the growth and yield of crops but also the nutritional quality. Though poultry manure significantly improved the dry matter accumulation and nutrients uptake over the control in this study, but not as much as plants treated with NPK fertilizer. This may be attributed to higher concentration of N, P and K in the NPK fertilizer than poultry manure. Furthermore, nutrients in chemical fertilizers are readily available for plant growth than organic fertilizer which releases their nutrients slowly. Most of the nitrogen in poultry manure is in the organic form and need time to mineralize before becoming available to plant. However, the full benefit of organic manure may not be reaped in just one season of cropping. Organic manure improves soil structure over time increasing the soil's ability to retain nutrients. Furthermore, they are biodegradable and environmentally friendly preventing toxins, salts, and chemicals build up in the soil unlike inorganic fertilizer whose persistent use destroys soil reaction and impedes the activities of soil microorganisms thereby making the soil acidic and toxic (Okoroafo *et al*., 2013).

In this study, sapropel did not significantly increase dry matter accumulation and nutrient uptake. The nutrients in the sapropel fertilizer may not also be readily available for plant immediate use. Agafonoya *et al.* (2015) reported that sapropel's positive effect is manifested in subsequent years of crop cultivation. This may suggest that when using sapropel as the nutrient source, little quantity of chemical fertilizer need to be added to the soil especially in the first season for short-lived crops. At the long run, it may cut down on the quantity of chemical fertilizer used.

Conclusion

NPK fertilized crop had the best performance in this study. However, for organic production of Indian spinach, poultry manure will serve as a better alternative to NPK fertilizer in the production of the crop than sapropel. Furthermore, watering at 2 days interval is adequate for optimum productivity and quality of the crop.

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