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The Response of Mulching to Soil Moisture Content and the Yield of Lettuce

Thelma Ntow[1], Eliasu Salifu[2]
Student[1], Lecturer[2]
Department of Agricultural Engineering,
School of Engineering,
University for Development Studies, Tamale, Ghana

Richard Osei Agyemang[3]
Lecturer[3]
Department of Environment,
Water and Waste Engineering, School of Engineering,
University for Development Studies, Tamale, Ghana

Abstract:- Mulch materials, whether organic or inorganic, prevent soil moisture loss, suppress weeds, improve and maintain healthy soil structure for plant development and yield. This study was carried out to evaluate the impact of mulch materials (Straw Mulch, Plastic Mulch and Neem Mulch) on soil moisture content, growth, and yield of lettuce as well as effective weed count with Zero Mulch as control. The result showed a significant effect ($P < 0.05$) of the mulch materials on soil moisture content, leaf area, leaf and weed count as well as yield in the form of fresh biomass of lettuce. The results suggest that the organic mulch (straw and neem) materials enhance the growth and yield of the lettuce plant better with an appreciable soil moisture conservation.

Keywords:- *Biomass, Chlorophyll index, Leaf area index, Neem mulch, Straw mulch, Plastic mulch, Zero mulch.*

I. INTRODUCTION

Potential evapo transpiration is an atmospheric situation in which soil loses moisture to the air at a rate through evaporation and transpiration. Available soil moisture decreases as soil dryness increases, and as a result, transporting water to the interface becomes small to fulfill the requirement of atmospheric conditions (Jensen et al., 1971). On the other hand, the dryness of the soil increases the pace of water loss from the surface and reduces the amount of soil moisture available to the plants. When the evaporative demand is low in an environment with more soil moisture that would have evaporated, the rate of water loss is reduced (Philip, 1957). However, moisture accessibility is one of the essential limiting factors, which directly affects the emergence, growth and establishment of vegetable crops. This reaffirms the need for farmers to adopt soil water conservation methods such as mulching.

The efficient use of mulch materials improves the physical characteristics of the soil in that the bulk density of the soil is reduced. The application of mulch materials increases the infiltration rate of the soil, moderates the soil temperature and maintains a good conditions for plant growth (Ahmad et al., 2009). Mulching also improves the microclimatic condition of plants as well as reducing weeds, minimizing evaporation, and elevating the soil temperature (Kasirajan et al., 2012). Research has proved that vegetable yields have increased by mulching (Clough et al., 1990). Mulched soil keeps moisture better, becomes more constant, and boosts crop yield, minimizing the need for frequent irrigation (Farjana et al. (2006).

In dry and semi-arid environments where moisture stress has a significant impact on the development and growth of vegetable, crop productivity is extremely low (Ozkan and Kulak, 2013). Moisture stress in the soil is a major cause of low productivity, with some vegetable crops losing up to 86.3% of their yield (Teame et al., (2017). Weed infestation, in addition to moisture stress, has a significant impact on the fall in vegetable yield by competing for nutrients with the crops. Research proves that mulching is an improved water management and weed control strategy that can be embraced in such an environment. The performance of mulch materials in managing soil water and controlling weeds is a contributing factor to the productivity of the vegetables grown using this strategy. This research aims at finding the most effective mulch material suitable for growing vegetables, of which lettuce is used as the test crop for the experiment.

II. MATERIALS AND METHODS

A. Experimental Site

The experiment was conducted at the experimental site of the University for Development Studies, Tamale, Ghana (Figure 1) during the 2021 off season. The field was at latitude 90 25' N and longitude 0 0 58' W with an elevation of 170 m above sea level. The study area is characterized by a single rainy season that begins in May and ends in October with a mean annual rainfall of about 1100 mm. The soils are mainly savanna ochrosols and groundwater lateritic soils with 12.53 % organic carbon content.

Fig. 1: Experimental site

B. Experimental Design and Treatments Application

Lettuce was planted in the field under three different much material treatments namely; Rice Straw Mulch (Straw Mulch), Plastic Mulch, Neem-Extract Residue Mulch (Neem Mulch), and Zero Mulch as the control to the experiment to determine the effects of the various mulch materials on the yield and growth of the lettuce. The Experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

Each unit plot measured 3.0 × 1.0 m with 0.5 m alleys between plots and replicates. Due to the four treatments and three replications, there were a total of twelve-unit (12) plots in the experiment. After the soil and seedbeds were prepared, Eden lettuce seeds with good heat tolerance were nursed and transplanted at the fifth week. A planting distance of 10 cm and planting depth of 1.3 cm were applied per standard recommendations. This was followed by the application of the treatments (mulch materials) unto the various plots.

C. Crop Management and Water Application

Due to the susceptibility of lettuce to insect and pest attack, periodic insect and pest control was performed on each plot from the time of sowing the seeds through to the harvest period. Weeds were also controlled manually. The recommended rate of 24 litters of water per day, which equivalent to 8 mm of irrigation per day was applied to each plot every evening. The water was applied manually with a watering can.

D. Data Collection and Analysis

Soil moisture at the root zone of the lettuce was measured with a Delta-T soil moisture probe. The soil moisture probe is attached to a Delta-T Theta Meter, which contains an internal power supply. On activation, an electric current pass through two 16 cm long metals sensors pinned into the soil. The probe measures the moisture in the soil which is displayed as volumetric soil moisture content. Three soil moisture measurements were made on each plot every morning for three (3) weeks.

The chlorophyll of the leaves was determined with a chlorophyll meter at seven days internal, hence yielding three different readings. The number of leaves of the lettuce plant were obtained by directly counting the functional leaves on three sampled plants at seven days interval. The length and width of the leaves were measured with a rule to determine the area as shown in Eq. 1. Fresh biomass of lettuce was taken by weighing the leaves right after harvest, whilst dry biomass was taken by oven drying the fresh biomass after harvest at a temperature of 80 °C for 24 hours. Data on weed count was taken by directly counting the number of weeds on each plot at seven days interval.

$$LA = L \times W \times r \qquad Eq\ 1$$

LA = Leaf Area, L = Leaf Length, W = Leaf Width, r = Correction Factor

The yield of lettuce (fresh biomass) was converted into kilograms per hectare (kg) and metric tons per hectare (t/ha) using the formulae below as shown in Equations 2 and 3 respectively

$$Kilogram\ per\ hectare\ (kg\ ha^{-1}) = \frac{1{,}000}{Area\ Harvested\ (m^2)} \times leaf yeild\ (kg) \qquad Eq\ 2$$

$$Metric\ ton\ per\ hectare\ (t\ ha^{-1}) = \frac{kilogram\ per\ hectare}{1{,}000} \qquad Eq\ 3$$

The R Studio data analytical software version 4.2.0 was used to analyze the data. Analysis of Variance (ANOVA) was used to determine effect of the mulch materials on soil moisture content at the root zone, as well as the growth and yield parameters of the lettuce at a significance level of 5 %. Tukey HSD (Honest Significant Difference) was used to compare and separate treatment means.

III. RESULTS AND DISCUSSION

A. *Effect of Mulching on Soil Moisture Content*

The effect of the mulch materials on soil moisture content is shown in Figure 2: The analysis of variance showed a significant effect ($p < 0.05$) of the mulch materials on soil moisture content at the rootzone of the lettuce plant. The maximum average soil moisture (22.4 %) retained in the soil was recorded in the Plastic Mulch. The highest moisture retention in the plastic mulch may be attributed to the prevention of moisture escape by the plastic material. The Straw Mulch recorded an average of 22.0 % of soil moisture and then followed by the Neem Mulch with average soil moisture of 15.1 %. The least soil moisture was observed in the Zero Mulch with 12.6 %. Similar to the observation of Li *et al*. (2017), the reduced soil moisture in the Zero Mulch in relative terms, may be due to the exposure of the soil to direct solar radiation.

A time series analysis of the soil moisture in the rootzone over a three weeks period shows a dominance of soil moisture by the Straw and Plastic Mulches. Thought the Plastic Mulch averagely recorded the highest moisture, the Straw Mulch was dominant in four cases of the moisture readings i.e., D5, D9, D12 and D23. Figure 3 shows the time series of the soil moisture at the rootzones among the mulch treatments.

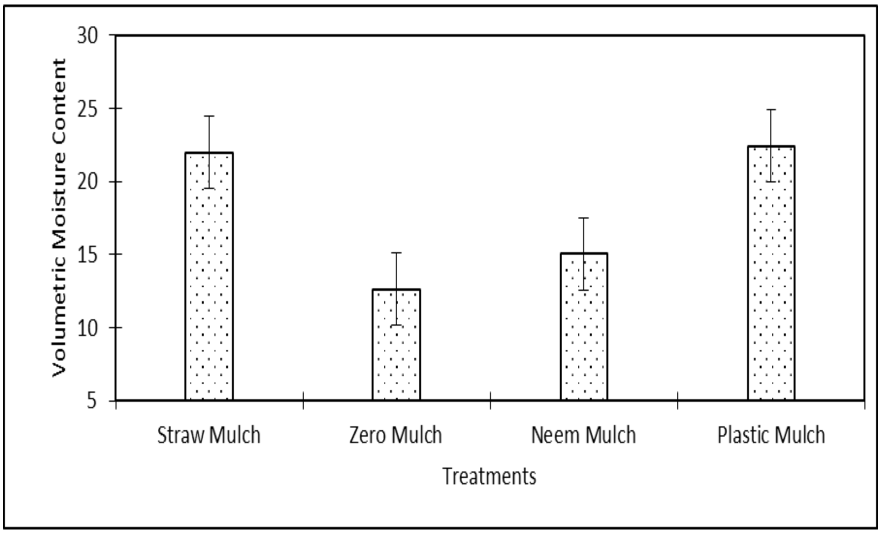

Fig. 2: Effect of mulch materials on soil moisture content

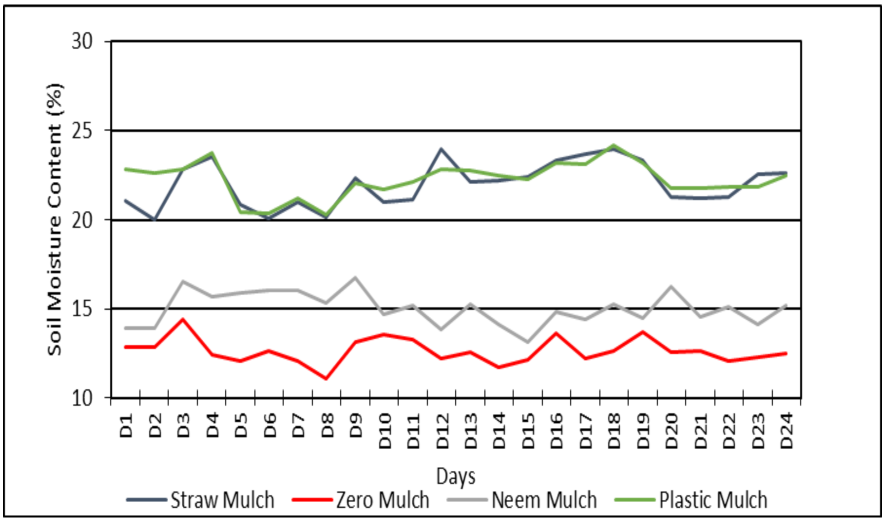

Fig. 3: Effect of mulch materials on soil moisture content daily

B. *Effect of Mulching on Chlorophyll Content of Lettuce*

Presented in Figure 4 is the effect of the various mulch treatments on the chlorophyll content of the lettuce. The analysis of variance showed an insignificant ($P > 0.05$) effect of the mulch materials on the chlorophyll content of the lettuce. However, the neem mulch treatment recorded a higher chlorophyll content compared with the other treatments. An experiment conducted by Mendoza-Tafolla et al. (2019) showed that the application of neem seed residue to the soil significantly influenced chlorophyll content of the crop leaves. The results showed a 25.8 chlorophyll content in the Neem Mulch. This was followed in decreasing order by Straw Mulch (24.1), Plastic Mulch (23.7), and Zero Mulch (23.1).

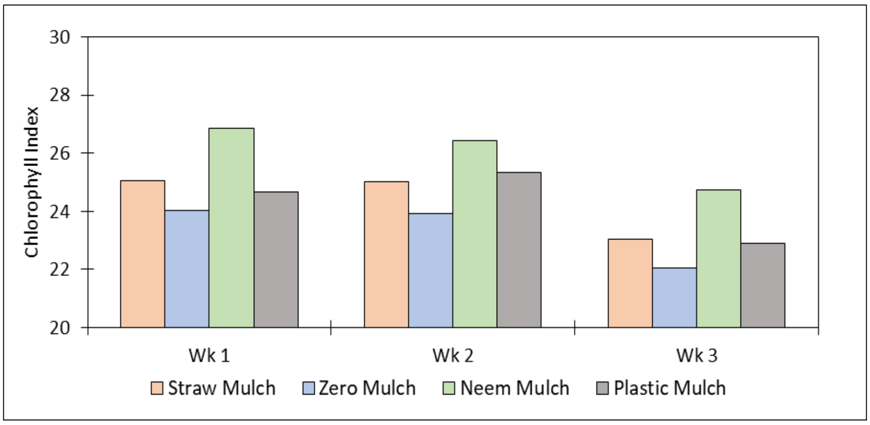

Fig. 4: The effect of the various mulch materials on chlorophyll content of lettuce

C. Effect of Mulching on Leaf Area of Lettuce

The mulch materials had a significant effect ($P < 0.05$) on the leaf area of the lettuce. The highest mean leaf area was observed in the Neem Mulch treatment with 121.9 cm2, and followed by Straw Mulch with 92.9 cm2. The Plastic Mulch had an average leaf area of 83.0 cm2 and the Zero Mulch being the least, had 81.7 cm2. Similarly, studies carried out by Sajid et al. (2013) recorded higher leaf area for pea plants cultivated under organic mulch compared to plants cultivated without mulch. Studies conducted by Makus et al. (1994) and Xue et al. (2013) also observed a significant effect in the plant growth parameters such as plant height, leaf area, leaf count and stem girth. Figure 5 shows the effect of the mulch materials on the leaf area of lettuce.

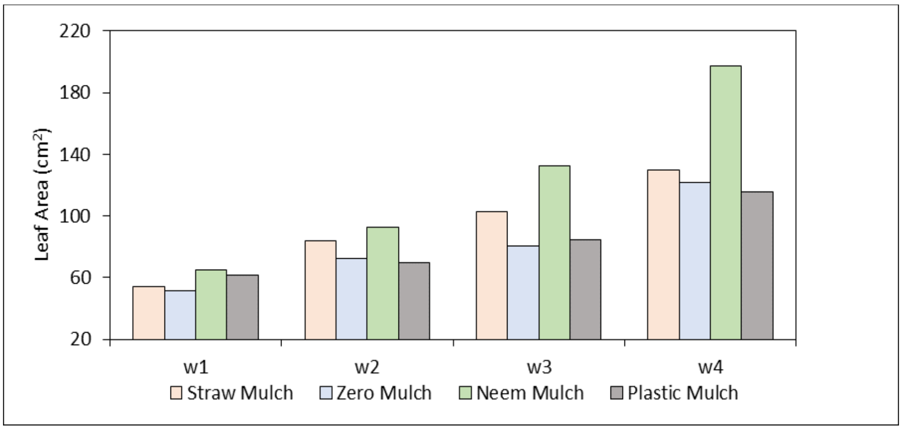

Fig. 5: The effect of the mulch materials on leaf area of lettuce

D. Effect of Mulching on Leaf Count of Lettuce

The analysis of variance showed a significant ($P < 0.05$) effect of the mulch materials on the number of leaves of lettuce. Figure 6 presents the results for the average leaf counts of lettuce for the mulch materials. The Neem Mulch recorded the highest average leaf count of 61.8. This was followed in a descending order by the Straw Mulch, Plastic Mulch and Zero Mulch with 58.8, 53.3 and 52.5 average leaves count respectively. A study by Yusuf et al. (2011) established that the application of neem seed residue could have improved the availability of nutrients to the lettuce by enhancing the mineralization and supply of readily available nutrients to the soil microbial community.

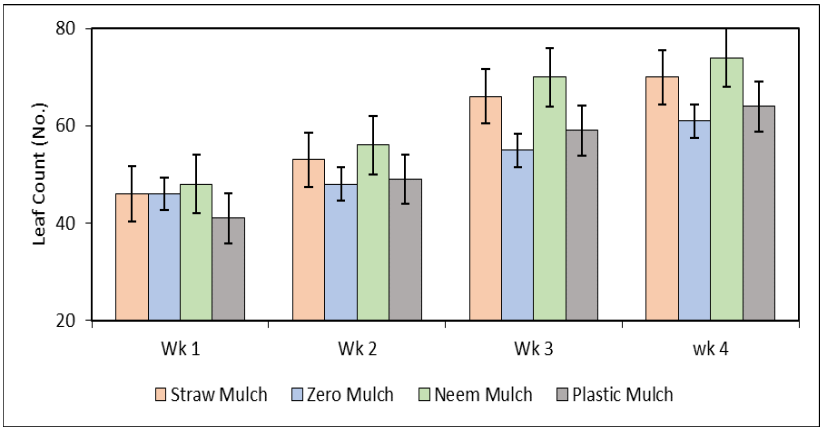

Fig. 6: The effect of mulch materials on the leaf count of lettuce

E. Effect of Mulching on Fresh and Dry Biomass of Lettuce

The analysis of variance showed a significant difference ($P < 0.05$) between the mulch materials on both the fresh and dry biomass of lettuce. The highest wight was observed in the Neem Mulch for both fresh (182.8 g) and dry (47.5 g) biomasss, as indicated in Figures 7. This was followed by the Straw Mulch with (134.8 g) and (25.3 g) for fresh and dry biomasss respectively. The Plastic Mulch had fresh and dry biomasss of (93.6 g) and (19.4 g) whilst the Zero Mulch had the least fresh and dry biomasss of (91.6 g) and (22.5 g) respectively. In similar studies on Okra, Eifediyi*et al*. (2015) observed significant fresh and dry biomasss of Okra in a neem seed cake mulch.

The yield of lettuce was taken as fresh biomass after harvest. In terms of tonnage, the Neem Mulch yielded 25.4 t h^{-2} of fresh biomass whilst the Straw Mulch yielded 18.4 t h^{-2} of fresh lettuce. The Zero Mulch and Plastic Mulch yielded 13.0 t h^{-2} and 13.0 t h^{-2} of fresh biomass respectively. A study by Toth *et al*. (2008) concluded that straw mulch treatments are promising organic mulches with a relatively high yield as compared to the undegradable polyethylene mulches. Also, De Silva and Cook (2003), similarly observed an increase in yield with straw mulch which enhanced the soil physical conditions and stability of the topsoil. In addition, rice straw mulch has been reported by Adisarwanto (1985) to have increased the grain yield of soybean from 0.95 to 1.25 t h^{-2}.

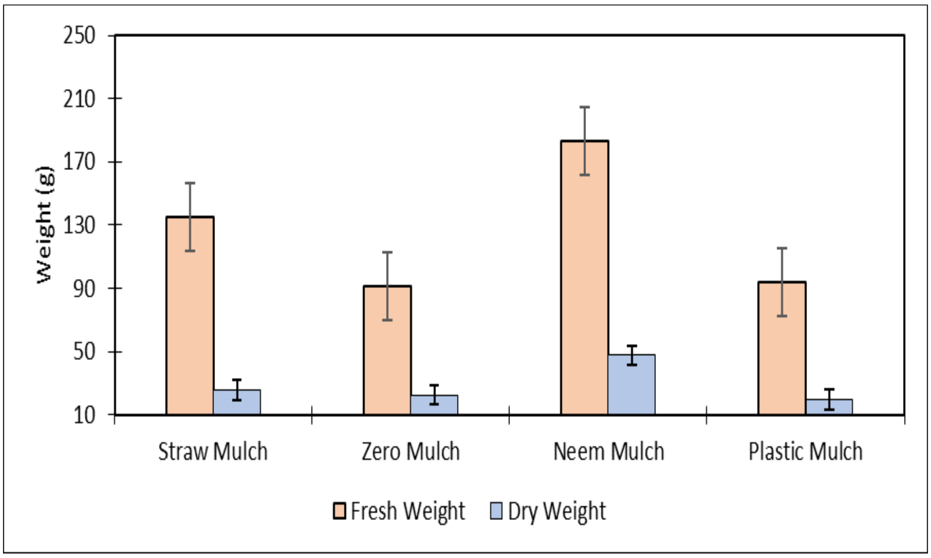

Fig. 7: The effect of mulching on fresh and dry biomass of lettuce

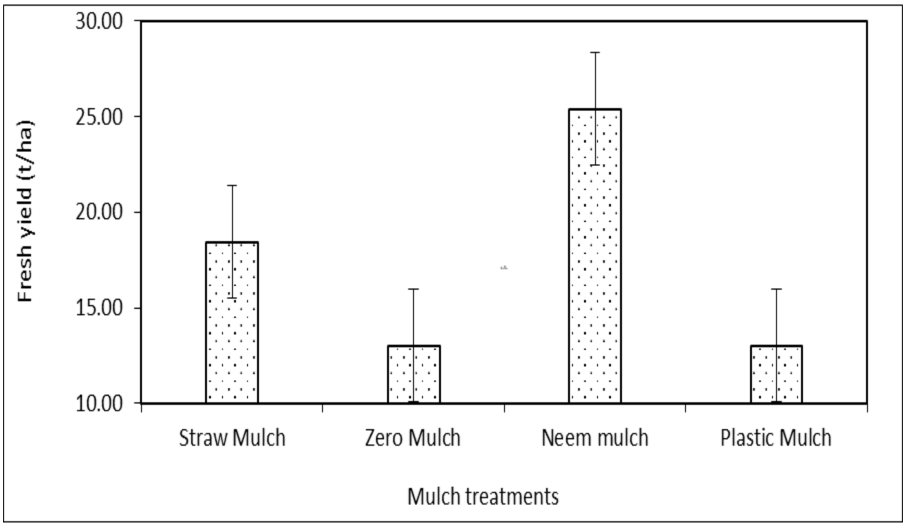

Fig. 8: The effect of mulch materials on the yield of lettuce (Fresh biomass)

F. Effect of Mulching on Effective Weed Count

The effect of the mulch materials on effective weed count is presented in Figure 9. The analysis of variance showed a significant ($P < 0.05$) effect of the mulch materials on weed count. The Plastic Mulch had close to zero (0.2) weeds. This was followed by the Straw Mulch (1.0), the Neem Mulch (5.0) and the Zero Mulch which had the highest average weed count of 15.5. The lack of weeds in the Plastic Mulch is obviously due to the absence of light as a result of the plastic material. The organic materials (straw and neem residue) were also effective in controlling the weeds compared to the Zero Mulch. A study by Ogundare et al. (2016) also found that neem residue used as a weed control method reduced weed infestations significantly.

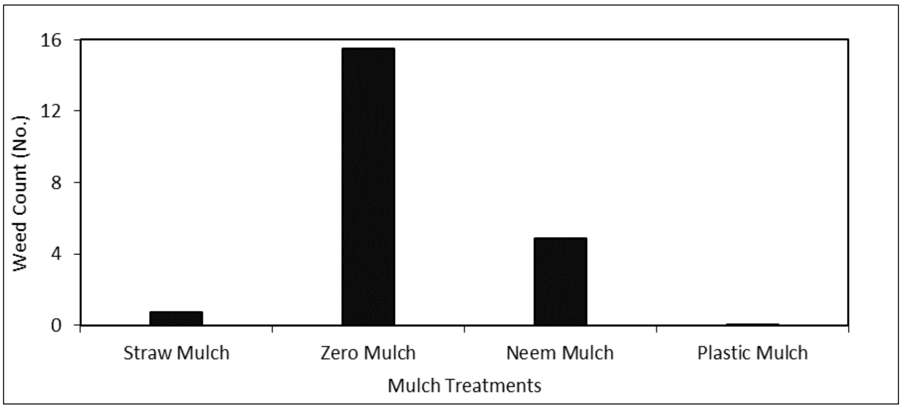

Fig. 9: Effect of the mulch materials on weed count

IV. CONCLUSION AND RECOMMENDATION

The experiment sought to assess different mulch materials in terms of soil moisture conservation and yield of lettuce.The outcome of the experiment shows that the mulch materials do not only conserve soil moisture but also enhance the yield of lettuce. The soil moisture was significantly affected by the mulch materials with the Plastic Mulch conserving more moisture relative to the Neem, Straw, and Zero Mulch. However, the Straw and Neem Mulches performed relatively better in terms of yield. The performance of the organic mulch materials (neem and straw) in the yield performance perhaps suggests their influence level and calls for the attention of farmers if more productivity is to be desired.

It is therefore recommended that, due to the organic nature of the Straw and Neem Mulches and their nutrient enriching and soil structure enhancement tendencies as well as ready availability, vegetable farmers should opt for them as mulch materials.

REFERENCES

[1.] Adisarwanto, T. (1985). The influence of planting method and mulching on soybean seed yield. pp. 215–217. In: Shanmugasundaram, S., Sulzberger, E. W., McLean, B. T. (eds.), Soybean in Tropical and Subtropical Cropping Systems. Asian Vegetable Research and Development Center, Shanhua, Taiwan.

[2.] De Silva, S. A., & Cook, H. F. (2003). Soil physical conditions and physiological performance of cowpea following organic matter amelioration of sandy substrates. Communications in Soil Science and Plant Analysis, 34(7-8), 1039-1058.

[3.] Eifediyi, E., Ahamefule, H., & Remison, S. (2015). Effects of neem seed cake on the growth and yield of okra (Abelmoschus esculentus (L.) Moench) in Ilorin, north-central Nigeria. Agro-Science, 12(2), 20. https://doi.org/10.4314/as.v12i2.3.

[4.] Farjana, S., Islam, M., A., & Haque, T. (2019). The effect of organic and inorganic fertilizers, and mulching on growth and yield of cabbage (Brassica oleracea var. capitata L.). Journal of Horticulture and Postharvest Research, 2(2), 95-104.

[5.] Hassan, M., N., Mekkawy, S., A., Mahdy, M., Salem, K., F., & Tawfik, E. (2021). Recent molecular and breeding strategies in lettuce (Lactuca spp.). Genetic Resources and Crop Evolution, 1-25.

[6.] Jensen, M., E., Wright, J., L., & Pratt, B., J. (1971). Estimating soil moisture depletion from climate, crop, and soil data. Transaction of the ASAE, 14(5), 954-959.

[7.] Kasirajan, S., & Ngouajio, M. (2012). Polyethylene and biodegradable mulches for agricultural applications: a review. Agronomy for sustainable development, 32(2), 501-529.

[8.] Li, C., Wang, Q., Wang, N., Luo, X., Li, Y., Zhang, T., & Feng, H. (2021). Effects of different plastic film mulching on soil hydrothermal conditions and grain-filling process in an arid irrigation district. Science of The Total Environment, 795, 148886.

[9.] Li, T., Shao, M. A., & Jia, Y. (2017). Characteristics of soil evaporation and temperature under aggregate mulches created by burrowing ants (Camponotus japonicus). Soil Science Society of America Journal, 81(2), 259-267.

[10.] Makus, D. J., TiwarI S. C, Pearso, N. H. A., Haywood J. D., & Tirks, A. E. (1994). Okra Introduction with Pine Straw Mulch. Agro-Forestry Sys. 27(2): 121-127.

[11.] Mendoza-Tafolla, R. O., Juarez-Lopez, P., Ontiveros-Capurata, R. E., Sandoval-Villa, M., Iran, A. T., & Alejo-Santiago, G. (2019). Estimating nitrogen and chlorophyll status of romaine lettuce using SPAD and at LEAF readings. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 47(3), 751-756.

[12.] Ogundare, S., K., Hinmikaiye, A., S., Oladitan, T., O., & Agbona, A., I., Technology, P., M., & Polytechnic, R. G. (2016). Effect of Neem Residues and Weed Control Methods on Soil Properties, Weed Infestation, Growth and Yield of Egg Plant (Solanum melongena L.) in Kabba , Nigeria. 21(3), 73–82.

[13.] Ozkan, A., & Kulak, M. (2013). Effects of water stress on growth, oil yield, fatty acid composition, and mineral content of Sesamum indicum. Journal Animal Plant Science, 23(6), 1686-90.

[14.] Philip, J., R. (1957). Evaporation, and moisture, and heat fields in the soil. Journal of Atmospheric Sciences, 14(4), 354-366.

[15.] Sajid, M., Hussain, I., Khan, I. A., Rab, A., Jan, I., Wahid, F., & Shah, S. (2013). Influence of organic mulches on growth and yield components of pea's cultivars. Greener J Agric Sci, 3(8), 652-657.

[16.] Teame, G., Tsegay, A., & Abrha, B. (2017). Effect of organic mulching on soil moisture, yield, and yield contributing components of sesame (Sesamum indicum L.). International journal of agronomy.

[17.] Toth, N., Fabek, S., Herak, M., Ivanka, Ć., & Josip, Ž. (2008). Organic Soil Mulching Impacts on Lettuce Agronomic Traits Author (s): Nina Toth, Sanja Fabek, Mirjana Herak Ćustić, Ivanka Žutić And Josip Borošić Source: Cereal Research Communications, 36 (6), 36.

[18.] Townsend, P. (2007). Supporting the ethical development and stewardship of seed Principles and Practices of Organic Bean Seed Production in the Pacific Northwest Table of Contents.

[19.] Xue, L., Wang, L., Anjum, S. A., Saleem, M. F., Bao, M., Saeed, A., & Bilal, M., F. (2013). Gas exchange and the morpho-physiological response of soybean to straw mulching under drought conditions. African Journal of Biotechnology, 12(18), 2360–2365. https://doi.org/10.5897/AJB12.902.

[20.] Yusuf, A.A., Iwuafor, E.N.O., Ladan, Z., Agbaji, A.S., Abdusalam, Z., Yusuf, H.A. (2011): Evaluation of neem-based compound fertilizer for crop production in Samaru, moist savanna of Nigeria. Journal of Agricultural Science and Technology, 235–243. Accession number 86164946