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Evaluation of Type and Application Timing of Indigenous Organic Materials on the Productivity of Maize (*Zea mays* L.) in Guinea Savannah of Ghana

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ABSTRACT

Timing of application of organic materials to seed sowing and the type of material used are fundamental to maximizing nutrient availability and productivity of maize. A pot experiment was carried out at the University for Development Studies, Nyankpala near Tamale to determine (1) the optimum planting date of maize after the incorporation of untreated organic materials (OM) and (2) the effect of different organic materials on maize productivity based on the concept of organic nutrient management. 4 × 5 factorial experiment laid out in a randomized complete block design and replicated thrice was used. The four organic materials used were: Biochar (B), Rice straw (RS), Rice husk (RH) and Grounded groundnut shell (GGS) and the five planting dates were: 7 days after incorporation (DAI) of OM (PD1), 14 DAI of OM (PD2), 21 DAI of OM (PD3), 28 DAI of OM (PD4) and 35 DAI of OM (PD5). 3L pots, each with a surface area of 0.0314m² were filled with soil mixed thoroughly with 156.2g OM, leaving the top 10 cm for watering. Parameters assessed were significantly influenced ($P \leq 0.05$) by the application of OM, such that days to seedling emergence, plant height, number of leaves, and total dry matter were optimised with the application of Biochar and Grounded groundnut shells. Rice straw and Rice husk supported the least growth performance of maize. Earliest crop seedling emergence was observed when maize was planted 21 - 35 DAI. Total dry matter production, similar to other measured parameters was optimised at 21 to 35 DAI of OM. Grounded groundnut shell likewise Biochar enhanced the parameters over Rice straw and the least was Rice husk. Resource poor farmers could utilise untreated Grounded groundnut shell and Biochar as organic fertilizer source in crop production when planting is done 21 days after OM incorporation in the Guinea savannah zone of Ghana.

Keywords: *Soil fertility, Biochar, Rice straw, Rice husk, Grounded groundnut shells*

INTRODUCTION

Maize (*Zea mays* L.) is the most important and cultivated cereal crop in tropical sub-Saharan Africa and the world and grown under irrigated and rainfed conditions. It is a rich source of food, fodder and feed and provides raw material for the industry. Products of maize like corn starch, corn flakes, gluten germ-cake, lactic-acid, alcohol and acetone are consumed as food or used by industries such as textiles. It has high carbohydrate content of about 71%, but low in protein and serves as the main source of carbohydrates for poultry industries in Ghana. However, annual grain production of maize in Ghana falls short of the demand (MoFA, 2010), due to several abiotic limiting factors.

Sanchez et al., (1997) reported that low soil fertility in smallholder farms is a major biophysical constraint to increasing per capita maize production in Africa. As such soil fertility restoration should be considered as an imperative investment for mitigation of poor rural livelihood. Several reports noted that, low inherent soil fertility has been identified as a major cause also for poor rice productivity (Buri et al., 2009; Issaka et al., 2009; Nyalemegle et al., 2009; Abe et al., 2010). Nyalemegle et al. (2009) attributed low inherent soil fertility to partly low levels of soil organic matter and attributed to the parent rock from the soil developed. Maobe et al. (2010) noted that grain yield of maize was most constrained by inadequate supply of nitrogen caused by insufficient application of fertilizer that were costly and unaffordable by smallholder farmers. Similarly, Kombiok et al. (2012) reported that small scale farmers in Ghana are poor and cannot afford the recommended rate of in-organic fertilizers for increased crop yields and therefore apply inadequate quantities. Consequently, crop grain harvests remain low perpetuating the poverty level of small scale farmers. Nyalemegle et al. (2009) and Issaka et al. (2012) noted that rice yields from continuously cropped fields declined, prompting the need to consider the use of organic fertilizers materials

There are various organic materials identified that have the potential to enhance the buffer capacity and the chemical nutrient status of agricultural soils in Ghana. Recently survey reports indicated the quantity, quality and distribution of various organic materials in Ghana (JIRCAS 2010; Issaka et al., 2011; Nakamura et al., (2012). Studies of Nakamura et al. (2012) reported that Rice straw, Cow dung and Human excreta were evaluated in rice lowlands in the Guinea savannah of Ghana and found as effective materials for improvement of soil fertility, soil physical properties and the soil buffer capacity when applied at 3t/ha. It was however, recommended that the materials of plant origin (rice husk, rice straw, saw dust) should be composted or charred to enhance soil fertility improvement. Issaka et al. (2012) noted that application of the materials (poultry manure, cow dung and rice husk) in combination with mineral fertilizer ensured increased security for enhance rice yields.

Timing of application of organic materials to date of sowing is fundamental to maximizing nutrient availability and efficient use of nutrients in organic manure. The longer the untreated manure stays in the soil before sowing the better, to allow for adequate mineralization for optimum release of nutrients. Thomsen (2005) stated that management of manure fertilizers is much more difficult than that of mineral fertilizers, primarily because manure and other organic fertilizers are affected by handling during storage and application as well as the timing of incorporation and distribution. Prolong period of application before sowing on the other hand, could increase N loss through the soil system, in comparison with shorter period of applications that lead to increased crop utilization of N (Thomsen, 2005). According to Havlin et al. (2005) 50 to 75% of total nitrogen contained in manure is organic and needs to undergo mineralization before it becomes available for plants, the remaining 25 to 50% is ammonium (NH_4^+) and is highly susceptible to volatilization. Pham et al. (2001) reported that rice straw can be composted rapidly within 45 days.However, studies fall short of elucidating the optimum timing of planting after the incorporation of a wider range of organic materials and the best organic material options for resource poor farmers. This study was therefore carried out to determine the optimum time for sowing after the incorporation of untreated four organic materials and select the most appropriate material for increased maize productivity in the Guinea savannah.

MATERIALS AND METHODS

Site Description

A pot experiment was conducted from April to June, 2014 in a greenhouse at the University for Development Studies, Nyankpala Campus near Tamale, in the Guinea savannah zone of Ghana. The greenhouse is located at the geographical position of latitude 09^o 24’44.4” N and longitude 00 º 58’49.7” W and at an altitude 183 m.

The area experiences unimodal rainfall with an annual mean rainfall of 1000 to 1022mm. The temperature distribution is fairly uniform with mean monthly minimum of 21.9°C and a maximum of 34.1°C. It has a minimum relative humidity of 46% and maximum of 76.8%. The soil of the study site is typical upland soil, developed from iron stone gravel and ferruginized ironstone brash (Adu, 1957). The soil was classified as a HaplicLixisol (FAO/UNESCO, 1997) and which was locally referred to as the Tingoli series (Serno and van de Weg, 1985).

Experimental Design and Treatments

The 4×5 factorial experiment consisted of 4 organic materials Biochar (B), Rice Straw (RS), Rice Husk (RH) and Grounded Groundnut Shell (GGS) and 5 planting dates after incorporation of organic material; 7 days (PD1), 14 days (PD2), 21 days (PD3), 28 days (PD4) and 35 days (PD5). The twenty treatments were laid out in a Randomized Complete Block Design and replicated three times.

Preparation of Soil Samples and Planting Materials

Perforated 3 liter plastic buckets were filled with garden soil to a height of 20cm leaving the top 10 cm to allow for adequate watering. Each bucket contained garden soil of volume 0.0629m^3 with a surface area of 0.0314m^2. Organic materials of weight 156.2g was mixed thoroughly with the soil and the pots laid out in three blocks with 40cm between blocks. Rice straw obtained from farmers’ fields in Bontanga and Nyankpala was chopped into fine pieces for easy pot incorporation. Rice husk was obtained from a rice mill of the Savannah Agricultural Research Institute, whilst grounded groundnut shells were obtained from a shelling machine at Nyankpala. The groundnut shells were grounded for easy incorporation. Biochar, a product obtained from burning agricultural residues at low oxygen concentration was prepared by burning rice husk at the required conditions.

Agronomic Practices and data collected

Hand-watering of the potted plants was done twice daily to promote the decomposition of the organic materials and the growth of the maize plants. Four maize seeds of variety “Wang data” were planted at stake and thinned-out two weeks after planting to three plants per pot. Weed control was done by hand to keep the pots clean. Data was collected on days to seedling emergence, plant height, leaf count and total dry matter production.

Statistical Analysis

The data collected were subjected to analysis of variance using GenStat statistical package. Treatment means were separated using Least Significant Difference at 5% significant level.

RESULTS

Days to Emergence

Statistically, number of days to maize seedlings emergence was significantly affected by the application of type of organic material ($p<.001$) and planting date after OM incorporation ($p<.001$). Biochar and grounded groundnut shells supported earliest seedling emergence, but rice straw gave similar timing (Figure. 1). Seeds planted to Rice husk gave delayed emergence although not later than rice straw.

Late planting date of 35 days after incorporation of OM supported earliest seedling emergence but this was similar to 21 days and 28 days planting dates (Figure. 2). Crop seedling emergence delayed with earlier planting dates of 7 days and 14 days after OM incorporation.

Plant Height

Plant height was affected by the application of the organic materials and date of planting after incorporation of OM as Biochar supported the highest plant height, but similar to grounded groundnut shells, whilst Rice husk produced the lowest plant height (Figure. 3).

Maximum plant height was attained 14 days after incorporation of OM, but 21 to 35 days planting dates gave similar heights, with the 7 days date producing shortest plants (Figure. 4).

Number of Leaves

Leaf production per plant was determined by type of organic materials and the days after incorporation of OM, such that Biochar (B) and grounded groundnut shells (GGS) produced the maximum number of leaves, which was more than observed with rice straw (RS) and rice husk (RH) (Figure. 5). Rice husk (RH) recorded the minimum number of leaves per plant at all timings of measurement. Generally, planting date of 35 days after incorporation of OM gave the highest number of leaves per plant but similar to dates of 14 to 28 days with the least at 7 days date (Figure. 6).

Total Dry Matter Weight

Total dry mater weight was influenced by both type of organic material application and planting date after incorporation of OM ($p<.001$). Although grounded groundnut shell (GGS) maximised total dry matter weight, similar production was with biochar (B), whilst rice straw (RS) and rice husk (RH) performed poorly (Figure. 7).

Planting date of 35 days after incorporation of OM gave maximum total dry matter weight, but equal production were at planting dates of 21 days and 28 days, with 7 days to 14 days dates lowering the biomass (Figure. 8).

DISCUSSIONS

Days to Emergence

Number of days to crop seedling emergence was affected by the type of OM applied (Figure 1) and time of planting after the incorporation of the OM (Figure 2) with Biochar and Grounded groundnut shell supporting early emergence relative to Rice straw and Rice husk probably due to higher C/N ratio of the rice materials.

Delayed planting after the incorporation of untreated OM promoted early crop emergence lending credence to findings that the organic materials required time for decomposition to reduce the C/N ratio to the level that could support plant growth (Pham et al., 2001). Therefore, optimum timing of planting is essential for efficient use of plant nutrients. For example, Pham et al. (2001) reported that rice straw can be composted rapidly within 45 days, although we observed that, under pot conditions, planting 21 days after the incorporation of the OM was adequate. Findings of Havlin et al. (2005) showed that 50 to 75% of total nitrogen contained in manure is organic and needs to undergo mineralization before it becomes available for plant uptake; with the remaining 25 to 50% being ammonium (NH_4^+) and susceptible to volatilization.

Plant Height

Plant height was affected by the type of the OM applied (Figure 3) and timing of application after incorporation of the OMs (Figure 4), with maize plants on Biochar (B) and Grounded groundnut shells (GGS) growing taller than supported by Rice straw (RS) and Rice husk (RH). In a maize trial, organic soil amendments recorded the highest plant height, dry weight, leaf area index and yield with or without chemical fertilizer (Efthimiadou et al. 2010). Similarly in rice, Masulili et al. (2010) reported that organic soil amendments improved plant height, number of tillers, and dry biomass. Nwaiwu et al. (2010) noted that organic manure when used alone or in combination with inorganic fertilizer enhances crop growth and yield, weed control, 50% reduction in expenditure on fertilizer, 40% topsoil retention capacity, mitigation of crude oil pollution on soils, control of soil erosion and salinity, and reduction of contamination from pesticide use.
Planting 14 days after incorporation of the OMs was enoughtomaximise plant height, as the parameter was probably not sensitive to the state of decomposition of the organic materials.

Number of Leaves

Number of leaves per plant was greatly influenced by type of organic materials (Figure 5) and planting date after incorporation of the organic materials (Figure 6), with Biochar (B) and Grounded groundnut shells (GGS) supporting maximum number of leaves. Widowati and Asnah (2014) reported that sole application of biochar increased the grain yield and relative agronomic effectiveness in maize production. Previously, Okoruwa (1998) observed significant increases in Leaf Area Index and dry matter accumulation in maize with biochar application.

Credibly, date of planting after incorporation of the untreated organic materials influenced leaf number differently, such that at least 14 days of delay was required to optimise leaf production by maize plants.

Total Dry Matter

Total dry mater weight was influenced by both type of OM (Figure 7) and date of planting after incorporation of OM (Figure 8) with grounded groundnut shell and biochar maximising production. Rice husk and, and rice straw supported the least amount of total dry matter accumulated. It is well documented that organic soil amendments improves crop growth as exhibited in increased plant height, number of tillers, and dry biomass (Thomsen, 2005; Masulili et al. 2010). Thomsen (2005) observed that management of manure fertilizers is difficult relative to mineral fertilizers, principally because its use is affected by handling during storage and application as well as timing of incorporation. Baronti et al. (2010) stressed that maximum dry matter increase (120%) was obtained with 60 Mg/ha biochar application. Also, Ogbonna and Obi (2005) observed that increased organic manure application could result in high dry matter partitioning for increased grain yield and harvest index.

Late plantings between 21 and 35 days after incorporation of the untreated organic materials favoured maximum total dry matter accumulation, relative earlier dates of 7 to 14 days. Onunka et al. (2012) reported that the highest economical root yield of sweet potato was attained with crop plantings of between 14-28 days after the incorporation of organic materials.

CONCLUSIONS

This trial was carried out to determine the type of untreated indigenous organic material that best promotes maize productivity and how long should the materials be incorporated into the soil before planting. Parameters measured were days to emergence, plant height, leaf count and total dry matter production. Results showed that Grounded groundnut shell (GGS) and biochar (B) enhanced crop growth over rice straw (RS), with Rice husk (RH) being the least supportive. At least is 21 days of delay was required after the incorporation of the untreated organic materials for seed planting to maximise maize production.

RECOMMENDATION

Resource poor farmers could utilize untreated Grounded groundnut shell and Biochar as organic fertilizers for effective crop production when incorporated into the soil 21 days before planting maize in the Guinea savannah zone of Ghana.

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Tables and Figures

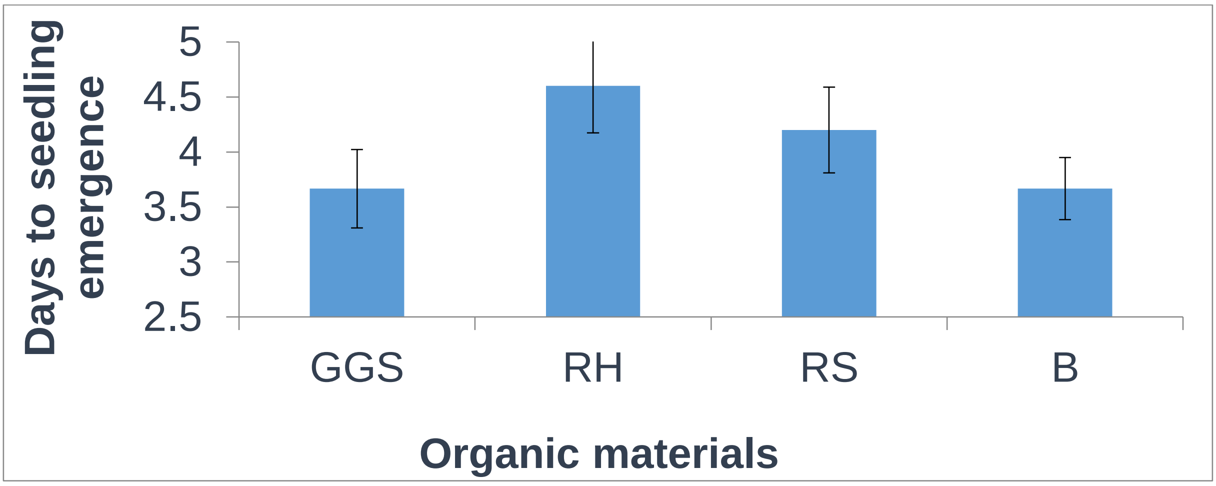

Figure 1. Effect of organic materials on days to seedling emergence. Bars represent SEM.

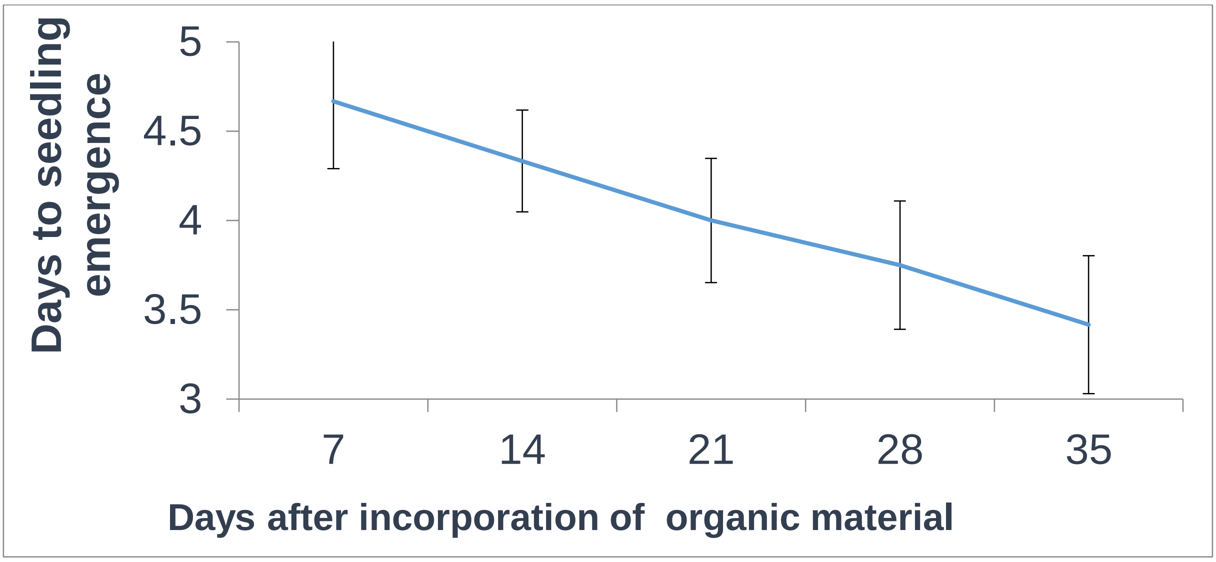

Figure 2. Effect of date of planting after incorporation of organic material on days to seedling emergence. Bars represent SEM.

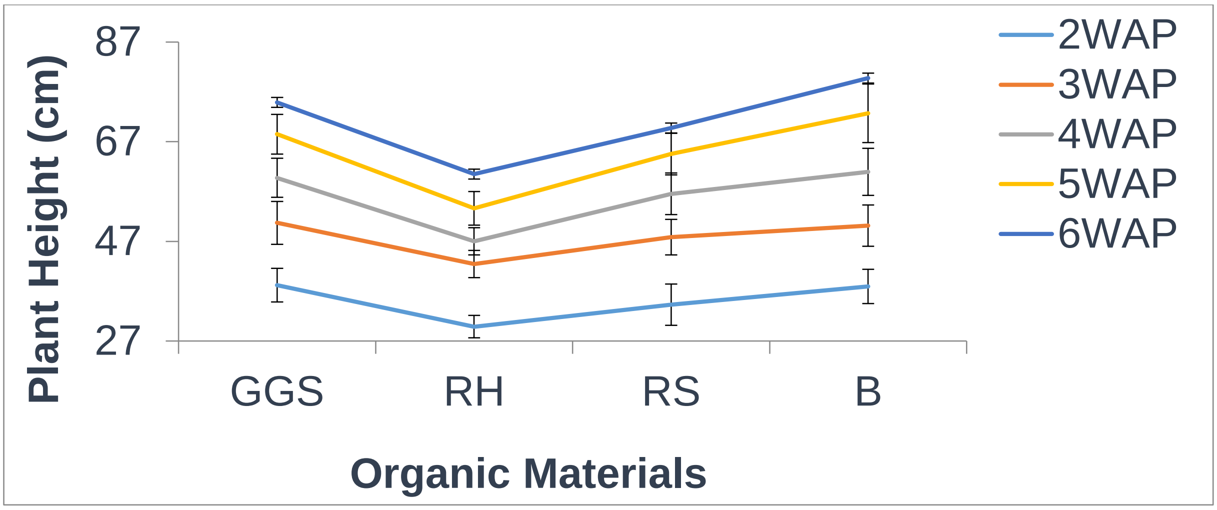

Figure 3. Effect of organic materials on plant height. Bars represent SEM.

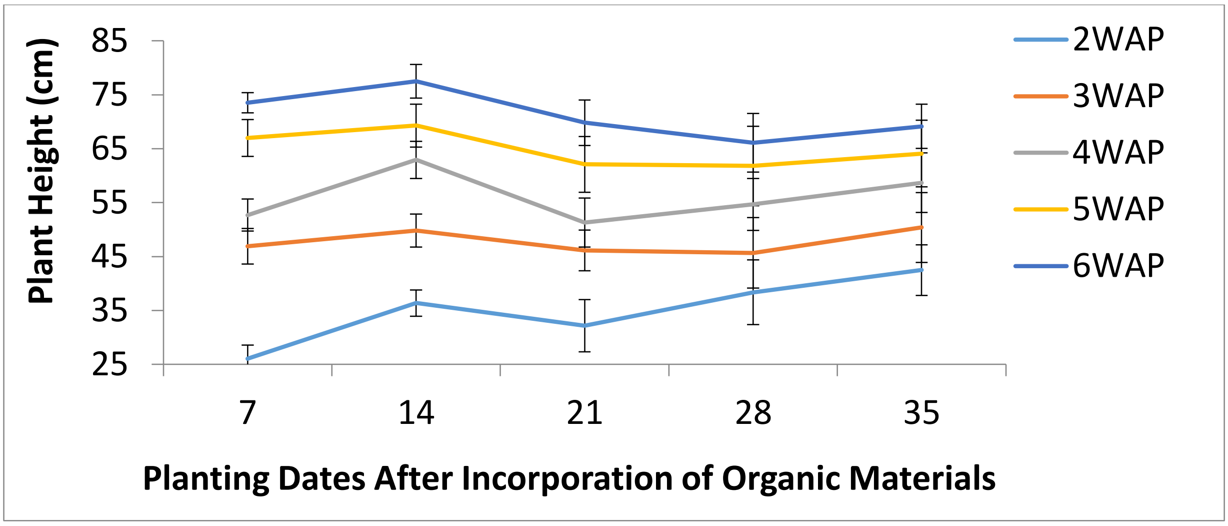

Figure 4. Effect of days after incorporation of organic materials on plant height. Bars represent SEM.

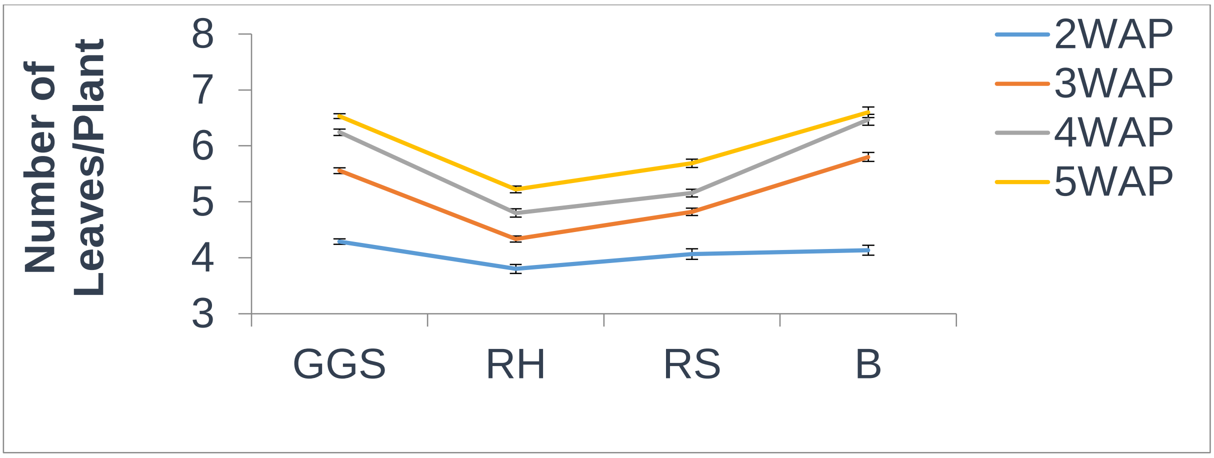

Figure 5. Effect of organic materials on number of leaves. Bars represent SEM.

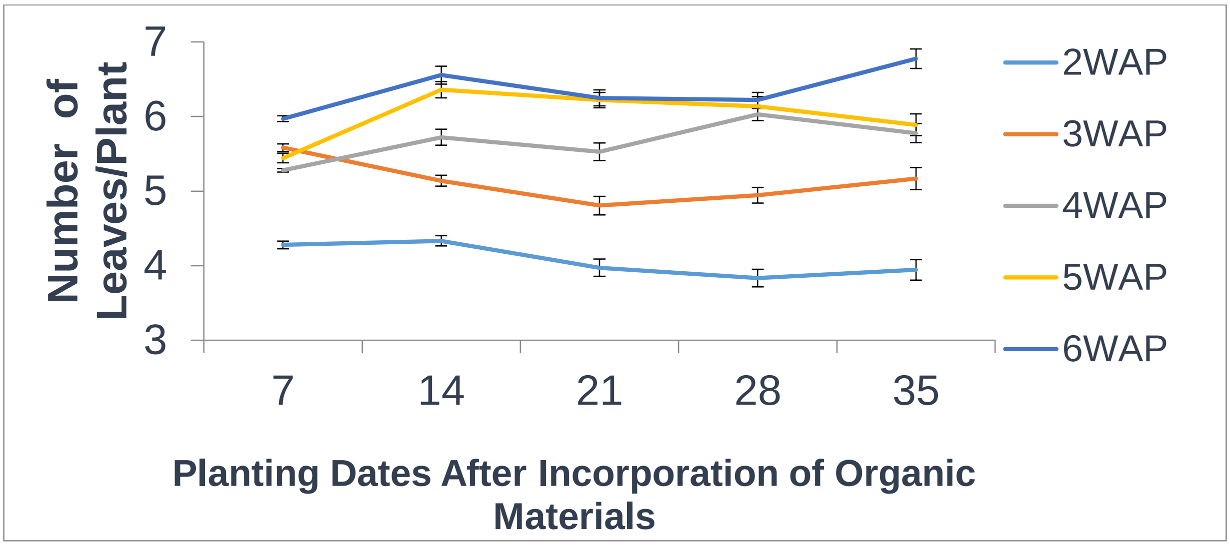

Figure 6. Effect of planting date after incorporation of organic materials on number of leaves. Bars represent SEM.

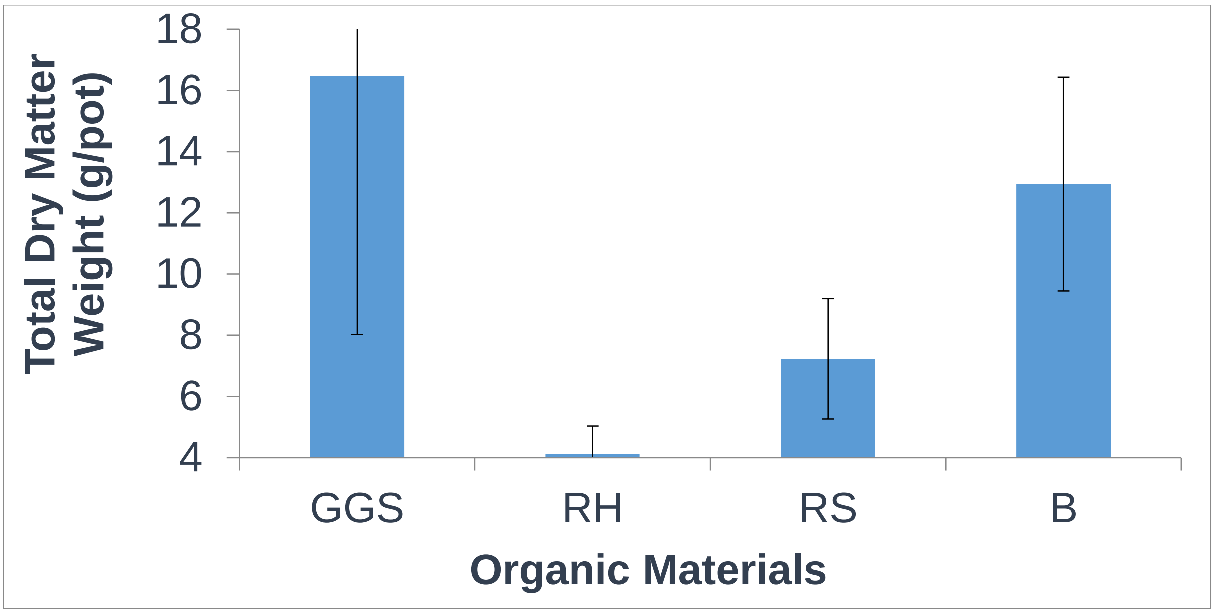

Figure 7. Effect of organic materials on total dry matter weight. Bars represent SEM.

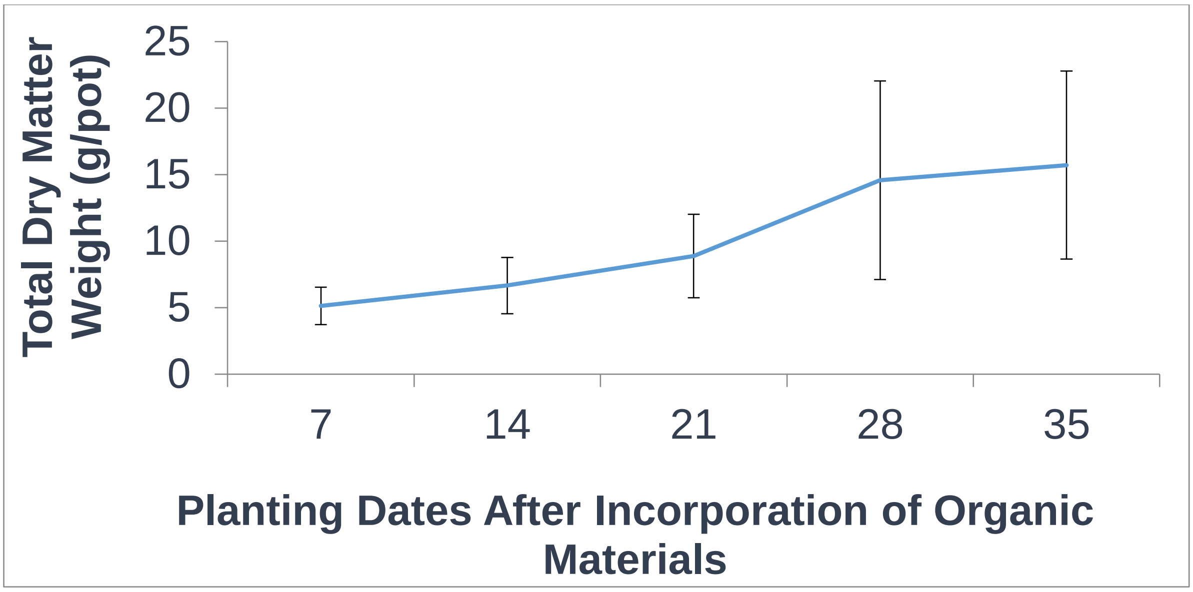

Figure 8. Effects of planting dates after organic materials incorporation on total dry matter weight. Bars represent SEM.